DIGITAL DC TO DAYLIGHT

2011 Communications Academy

Digital Track - Talk 2

Picking the Right Mode
and
Transmitting a Perfect Digital Signal
Moving beyond PSK-31 to MT63, DominoEX22 and Olivia

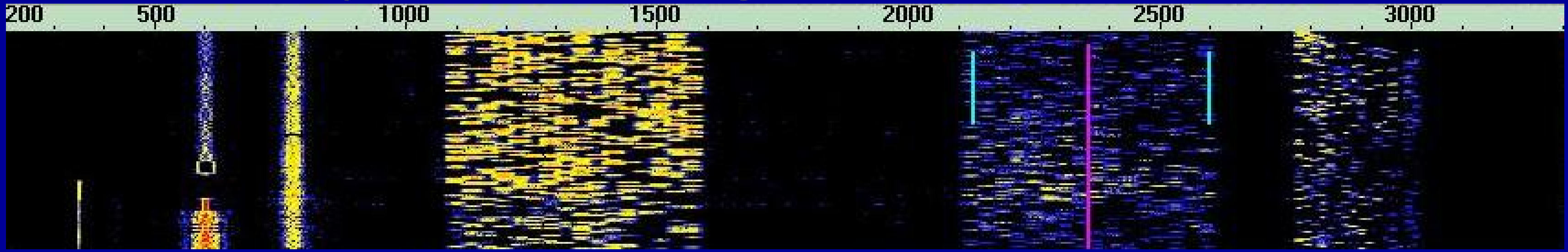
Clint Hurd, KK7UQ
Curt Black – WR5J

Clint KK7UQ

(Clint’s the one with the beard)

Curt WR5J

Why Use Digital Modes?



- **WE NEED THE HELP – The Future Looks Bad Here!!!**
- **Low Power – 10-20dB improvement over voice**
- **Spectrum efficiency – many conversations in bandwidth of one SSB QSO**
- **Great for reliable Communications – HF – VHF - UHF**
- **Many modes - choose your mode depending on conditions**
- **Emergency Communications – 100% integrity on complex messages – sent from One-to-Many – with low power or temporary antennas**
- **It’s FUN – Use it in your daily practice so proficiency is high**
- **Bottom of the solar cycle - works well, even under very poor conditions where phone QSO’s would be impossible!**
- **Perfect for a modern ham trapped in Urban Apartment land**

Mode	Seconds to Send Gettysburg Address	minimal S/N in dB
* SSB	120	9
Packet AX.25 1200Baud		8
Packet AX.25 300Baud		3
PSK-500	21	Approx 1
MT-63/2000	86	-2
Pactor 1 100 Baud		-4
** RTTY	301	-5.5
** Olivia 8/1000	256	-7
PSK63	139	-8
** Olivia 8/500	504	-11
**DominoEX22	98	-9
ALE 400		-9
** Olivia8/500	504	-11
**DominoEX11	188	-11
**PSK31	317	-11
** MFSK16	247	-13
***Reed-Solomon ID		-16
****JT65A		-24
****WSPR		-27

Hardware

- **Inexpensive Computer**
- **HF or VHF/UHF Radio/Antenna**
- **Sound Card Interface?**
- **Or, maybe just the Mic built into your laptop?**

Today’s discussion

- Basic digital communication using SSB radio, Personal Computers, Sound Cards and Serial Ports – BPSK31 used as an example.
- Discussion of advanced modes: MT63, DominoEX22 and Olivia with focus on theory, setup and use.

Questions?

Any time during the presentation

Presentation on the Web

- A copy of this presentation is found on:
- Washington Digital site:
  - http://groups.yahoo.com/group/wa-digital/
- Puget Sound Digital site:
  - http://tech.groups.yahoo.com/group/P-S-Digi-Hams/
- Communications Academy site:
  - http://CommAcademy.org

Why the Excitement Over Digital Modes?

- Well suited to low power, simple antenna operation
- Works well for local communication on HF and VHF as well as DX contacts on HF.
- Inexpensive, straightforward integration of computer and transceiver
- Free or low cost software available for Windows PC, MAC, Linux

Sound Card Mode Basics

- Basic concept of modulated sound card modes
- Interfacing
- The PSK Signal
- Setting Audio Level
- Software - Features & Tools

Basic Concepts

- Modulated Audio, transported over ham phone transceiver
    - SSB, usually USB
    - FM radio
- Bandwidth limitation of modulated signal: 2.7 kHz

Basic Concepts

- An audio tone modulating a SSB transceiver in Upper Side Band, produces an RF signal at the dial frequency of the radio + the audio frequency of the tone.
- Example: Radio at 14.070 mHz modulated with a 1500 Hz tone produces a signal at 14.071.500 mHz

Basic Concepts

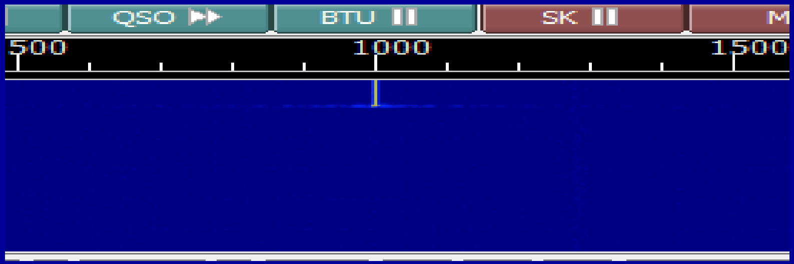
- If you modulate the audio tone with data in a mode such as PSK (Phase Shift Keying), a PSK signal will be produced at the radio dial frequency + the modulated audio tone frequency.
- Example: SSB Radio at 14.070 mHz when applied with a PSK modulated 1500 Hz carrier produces a PSK signal at 14.071.500 mHz

Basic Concepts

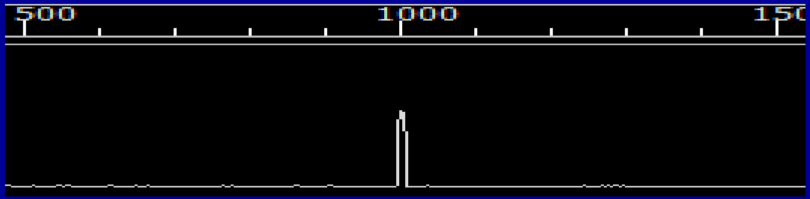
- Careful attention to linear operation
  - Audio level must be adjusted so that the signal is not clipped
- Control of output power
  - Modes are often high duty cycle
  - Keep average output power under 50% of rated CW power.

Single Tone

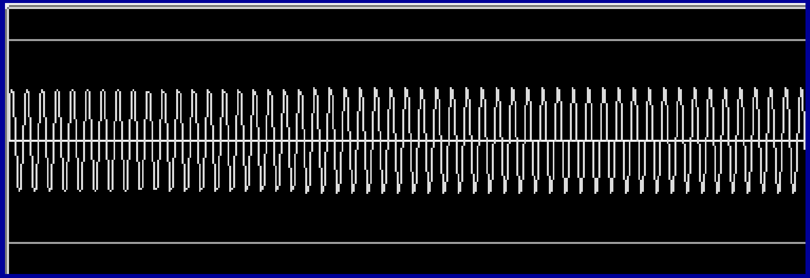
- Waterfall



- Spectrum



- Analog wave

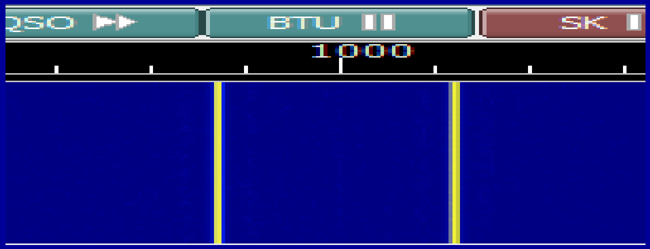


- Average power

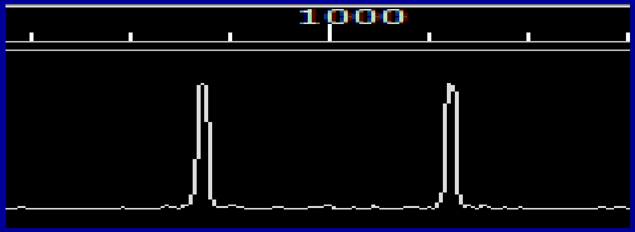
  = 100% of Peak Power

Two Tones

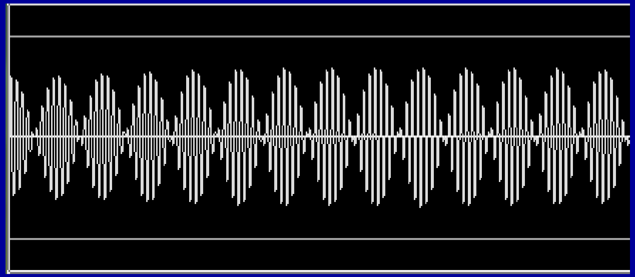
- Waterfall



- Spectrum



- Analog scope view



- Average power

  = 60% of peak power

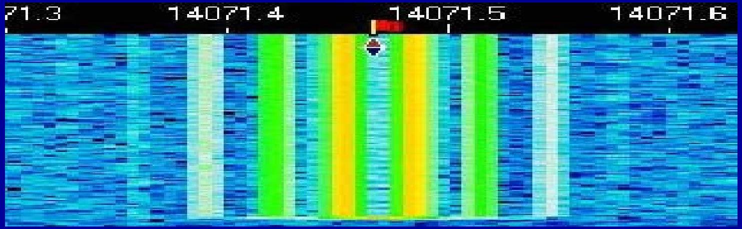
Multiple Simultaneous Tones Must Be Kept Linear

- Clipping an audio signal that has multiple simultaneous tone components will cause production of multiple side-bars that end up in the transmitted signal.

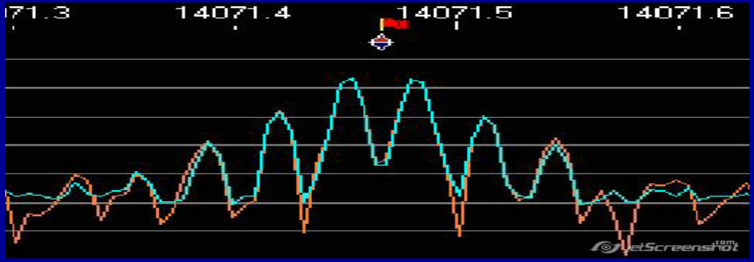
- Use the ALC meter on your transceiver to keep your signal clean.

Two Tones – Over Driven Signal

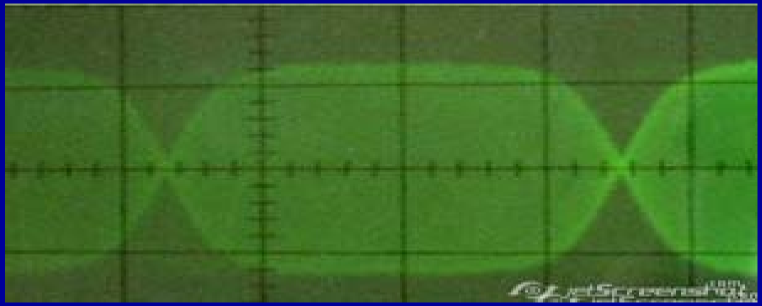
- Waterfall



- Spectrum



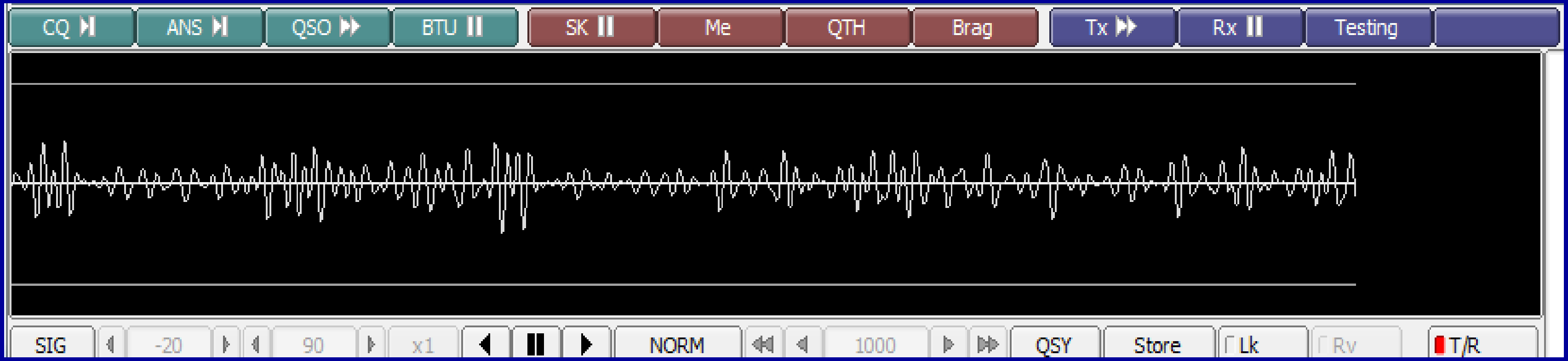
- Analog scope view



- Clipped signal causes multiple sidetones & 200 Hz wide signal vs original at 31 Hz

More Than Two Tones

- There are some modes that transmit many tones at the same time
  - MT63 & Winmor
- Special care must be taken when adjusting the audio drive for these modes to avoid clipping on peaks

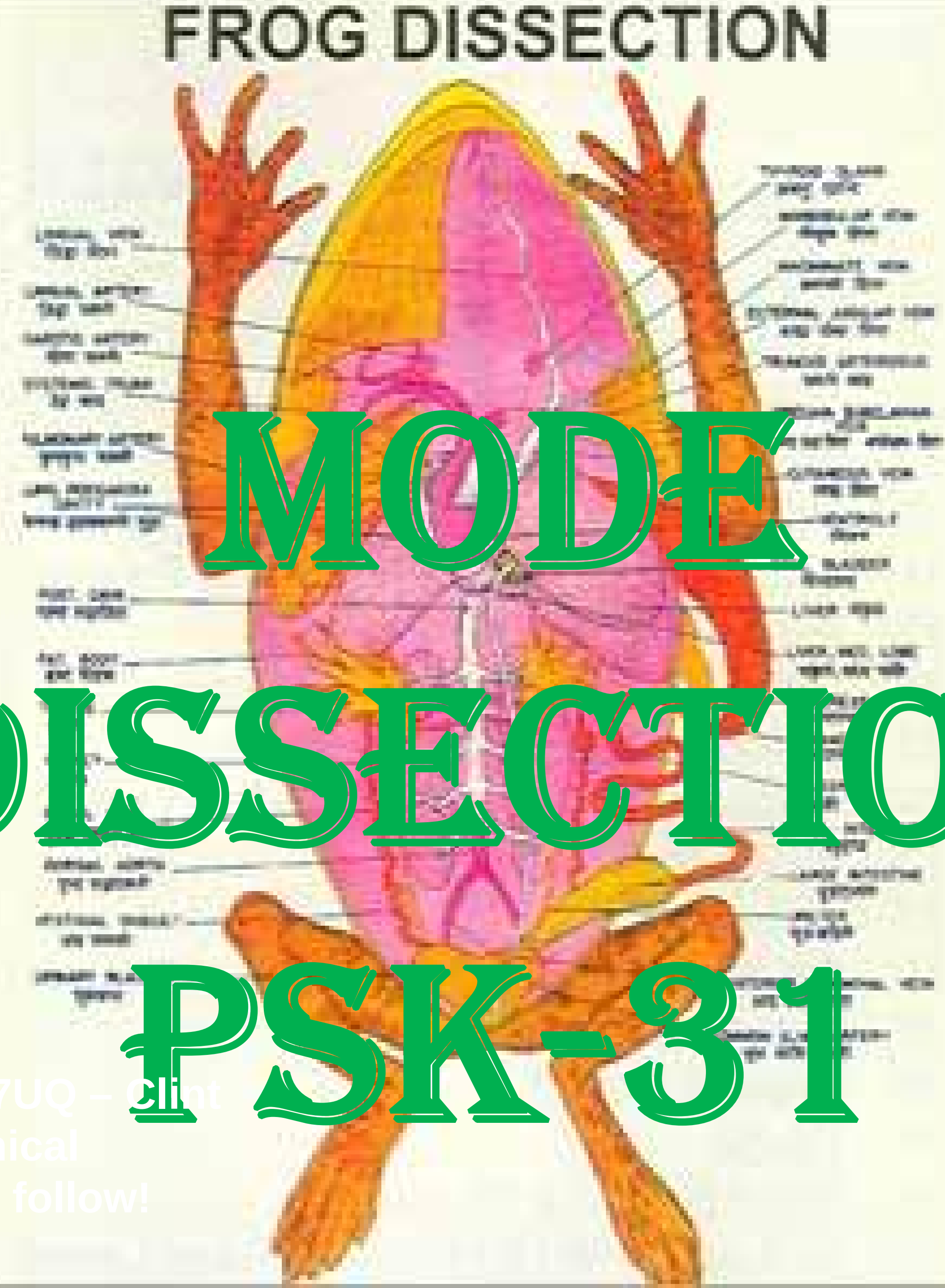


Avoid Running Your Transceiver at Too High a Power Level

- Sound card modes run at 60 to 100% duty cycles.

- Adjust the audio drive to produce 30 to 50% average power level to avoid overheating your transceiver finals.

- 30 to 50 watts produces a very effective signal for these narrow band width modes.



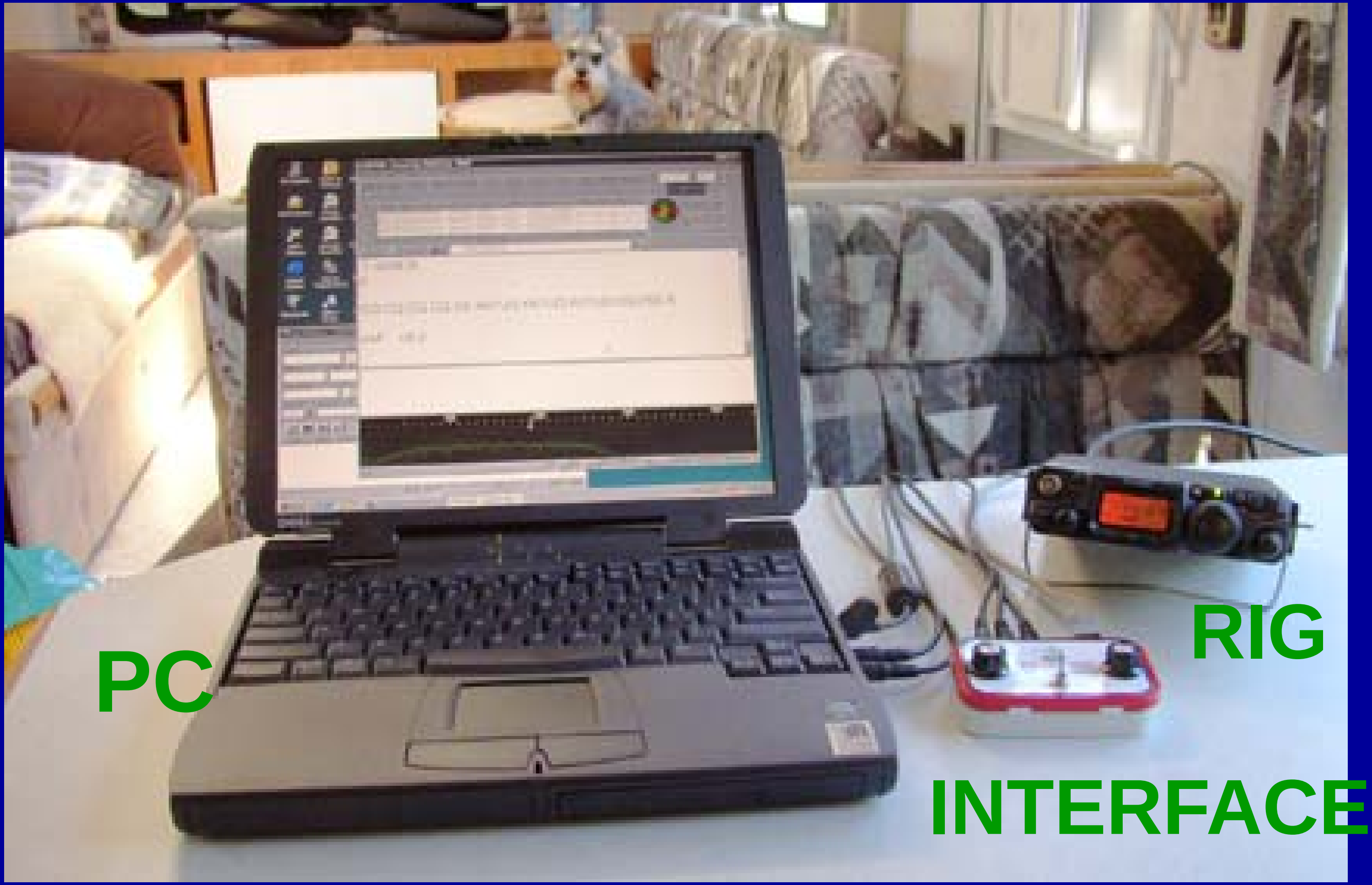
MODE DISSECTION PSK-31

Thanks to KK7UQ – Clint Hurd for technical Information to follow!

Discussion of BPSK31 Mode

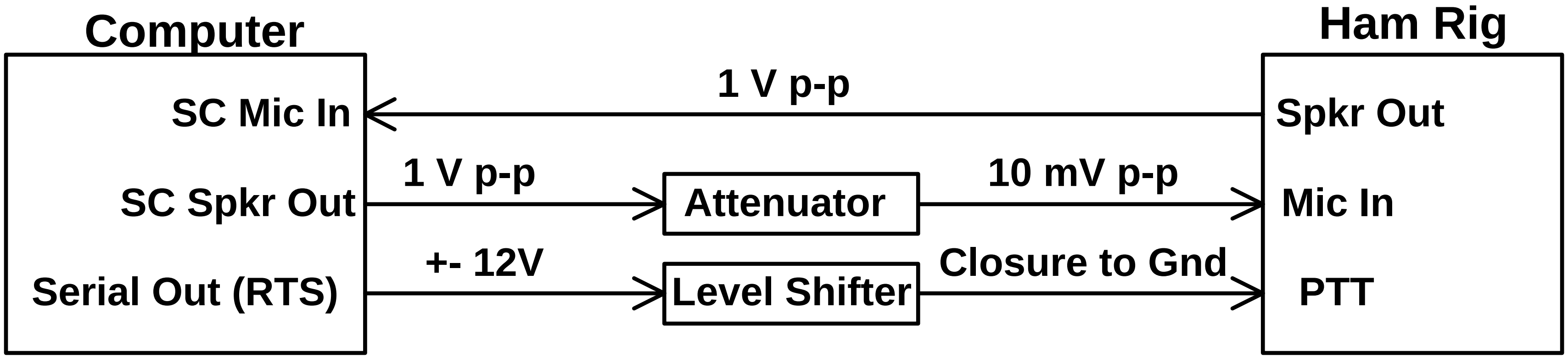
- Physical Connections – Interface
- Theory & Implementation of BPSK31
- Software

Typical Station Setup for Sound Card Modes



Schnauzer Optional

Basic Hardware Interface



Computer

SC Mic In

SC Spkr Out

Serial Out (RTS)

1 V p-p

1 V p-p

+- 12V

Attenuator

Level Shifter

10 mV p-p

Closure to Gnd

Ham Rig

Spkr Out

Mic In

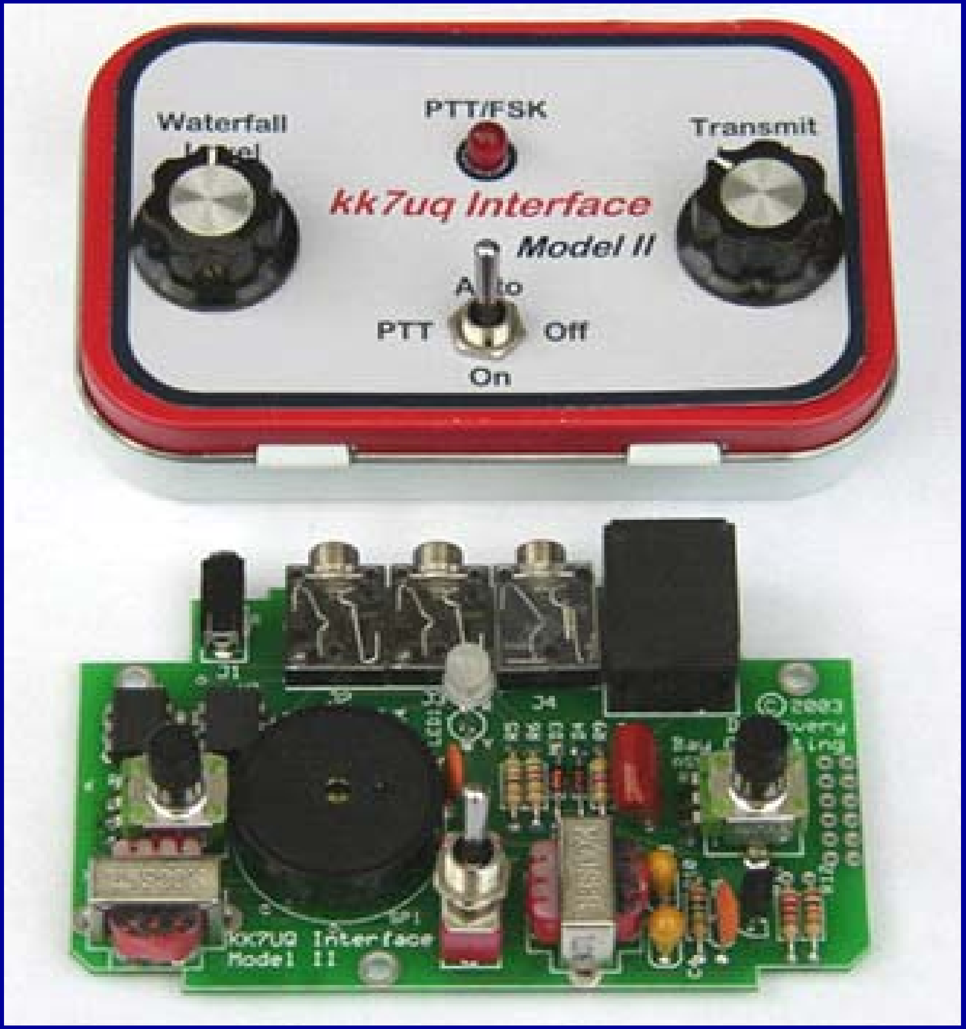
PTT

Sound Card Modes - Interface Block Diagram

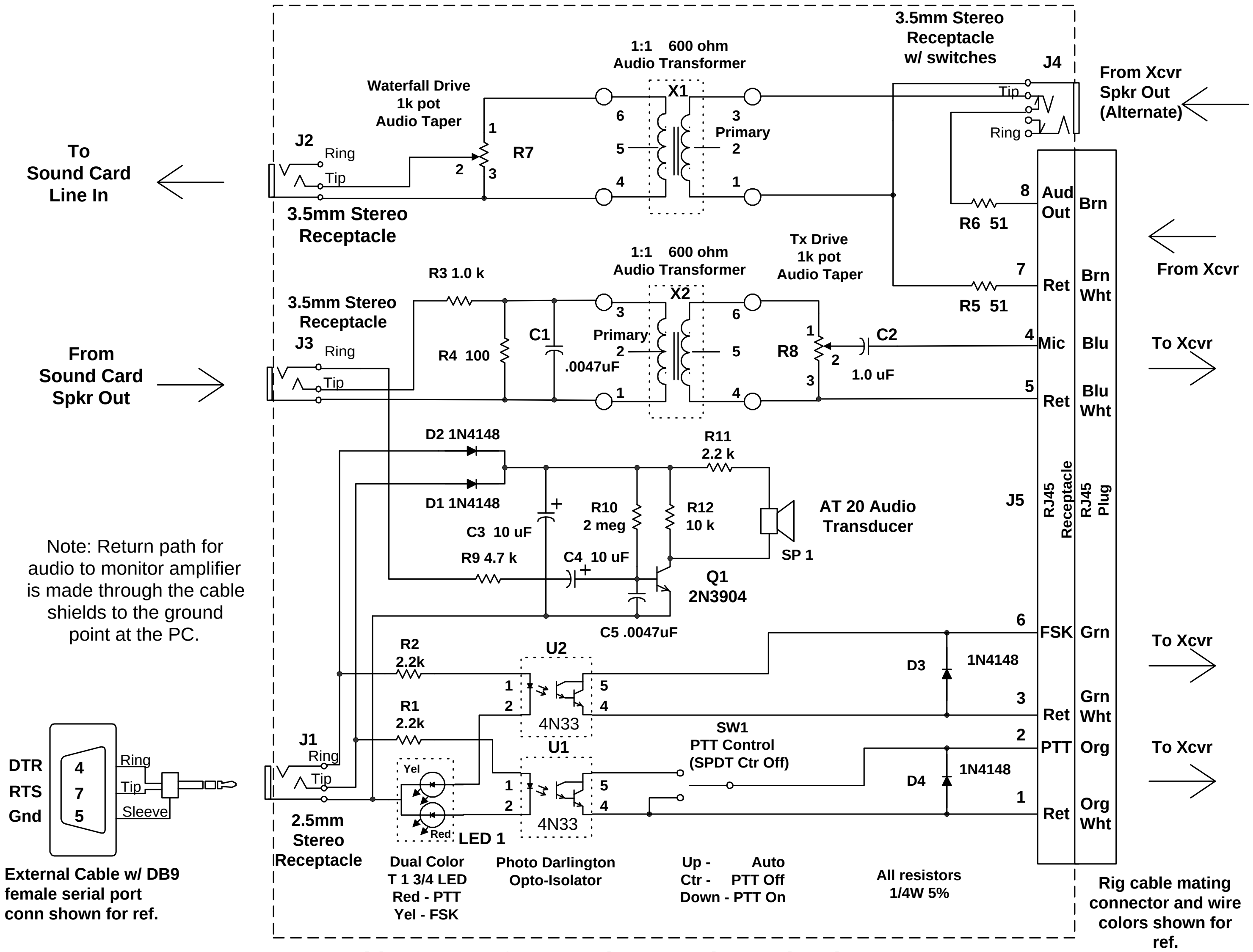
Basic Sound Card Interface

- Use PC sound card for signal encode / decode
  - Isolate audio path with transformers
  - Provide level shifting in interface
- PTT control
  - Use Serial Port RTS for PTT control
  - Or Generate from audio signal

Basic Sound Card Interface



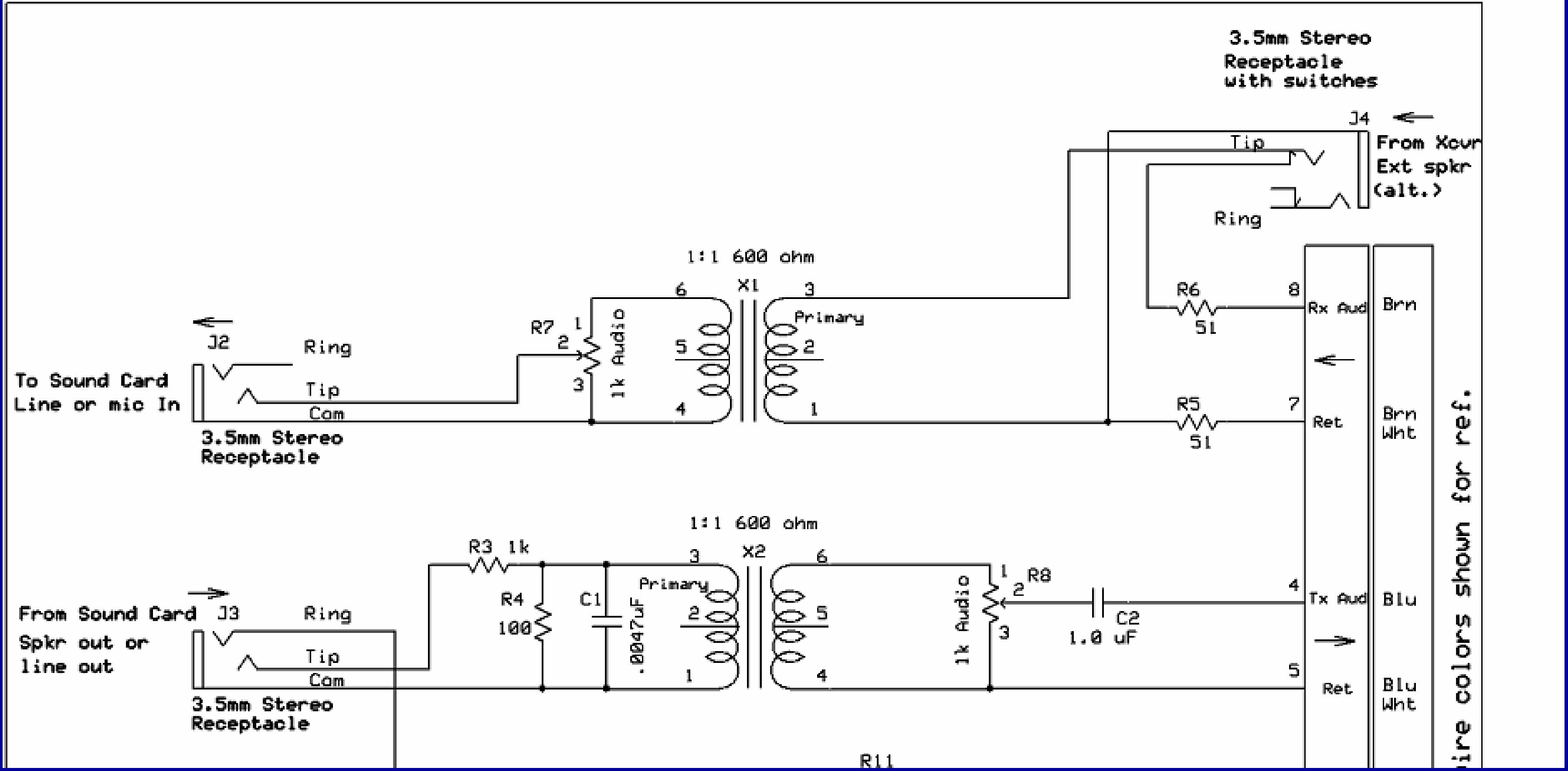
Basic Sound Card Interface



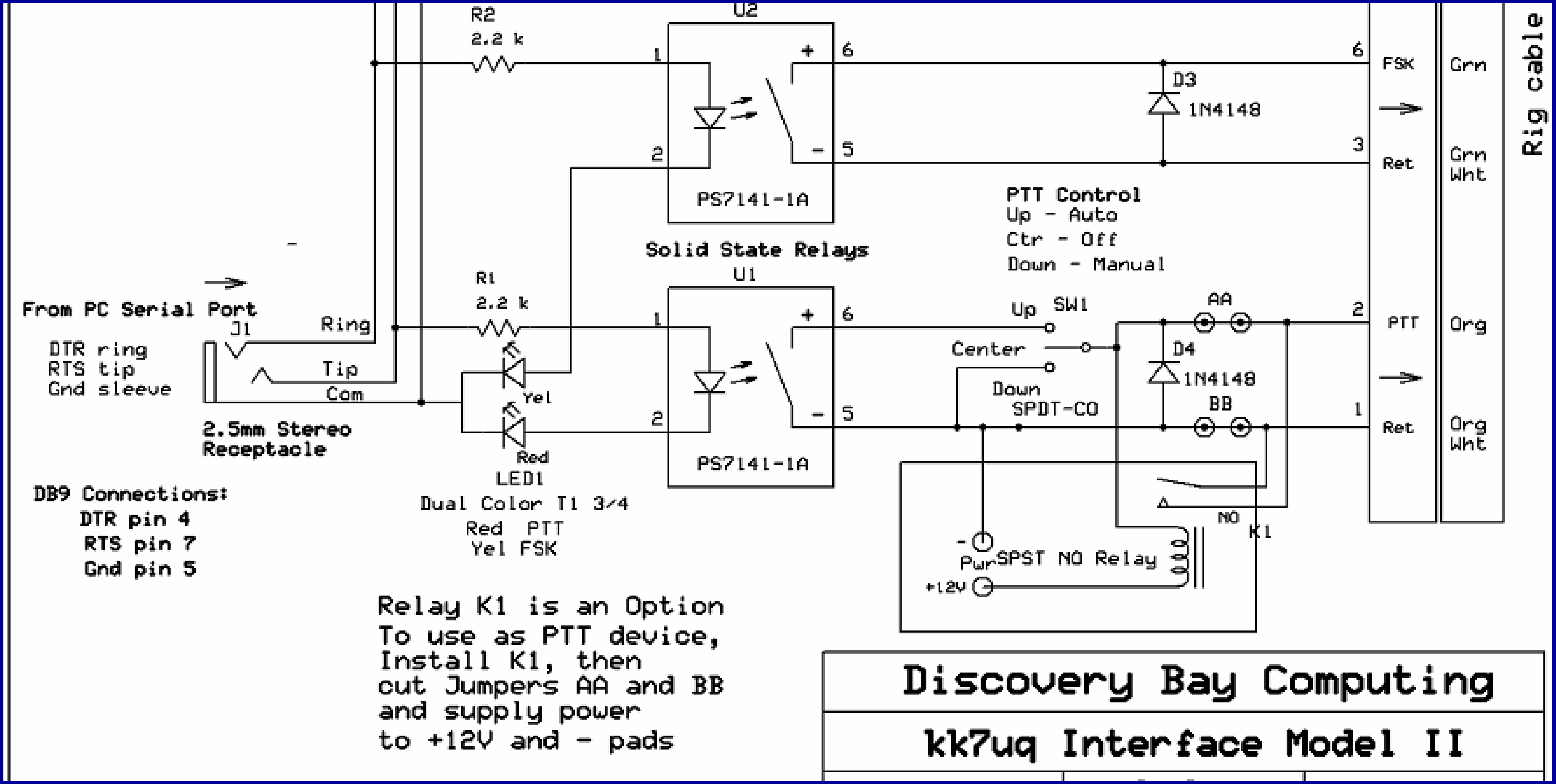
Note: Return path for audio to monitor amplifier is made through the cable shields to the ground point at the PC.

kk7uq Interface Model II - Schematic Diagram

Audio Transformer Isolation



Using RTS to Generate PTT



DB9 Connections:
DTR pin 4
RTS pin 7
Gnd pin 5

Relay K1 is an Option
To use as PTT device,
Install K1, then
cut Jumpers AA and BB
and supply power
to +12V and - pads

Discovery Bay Computing

kk7uq Interface Model II

VOX for Rig PTT Control?

- Rig VOX can be used to “key” the rig instead of a serial port control line but difficult to do in practice:
  - Audio drive level to trigger VOX reliably may exceed level which gives a clean signal
  - Any PC audio keys the rig
- Positive PTT control is more reliable
  - PTT can lead / lag signal

VOX Exception – Signal Link

- The Signal Link interface implements a VOX like PTT control which does reliably trigger PTT when a signal is seen

- This does not use the rig VOX, but instead monitors the pre-attenuated audio signal within the interface to create the PTT signal when signal is seen

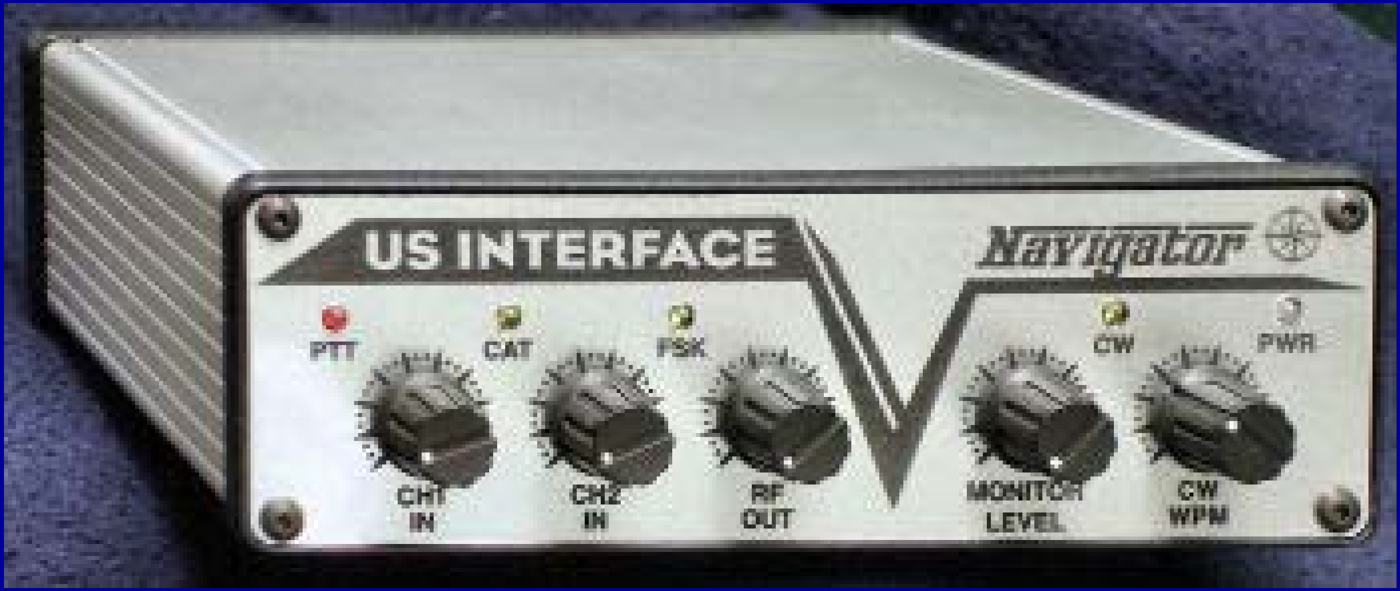
Sources for Basic Interfaces

- BuxCom - Rascal
  - www.buxcom.net
- MFJ – several models
  - www.mfjenterprises.com
- Saratoga – EZ-Psk
  - www.SaratogaHam.com
- TigerTronics - Signal Link
  - www.tigertronics.com
- West Mountain Radio - RigBlaster
  - www.WestMountainRadio.com

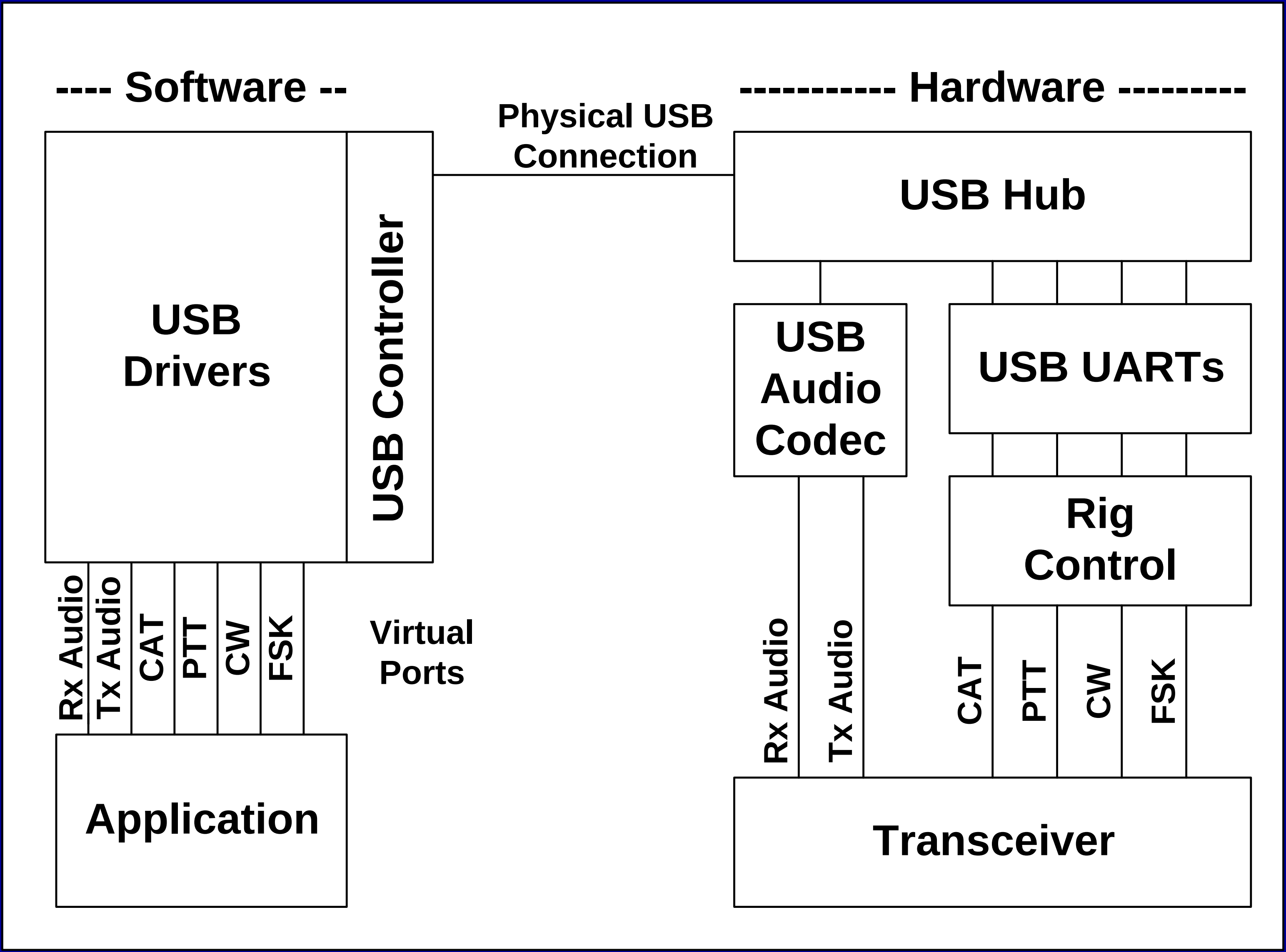
Full Featured Interface

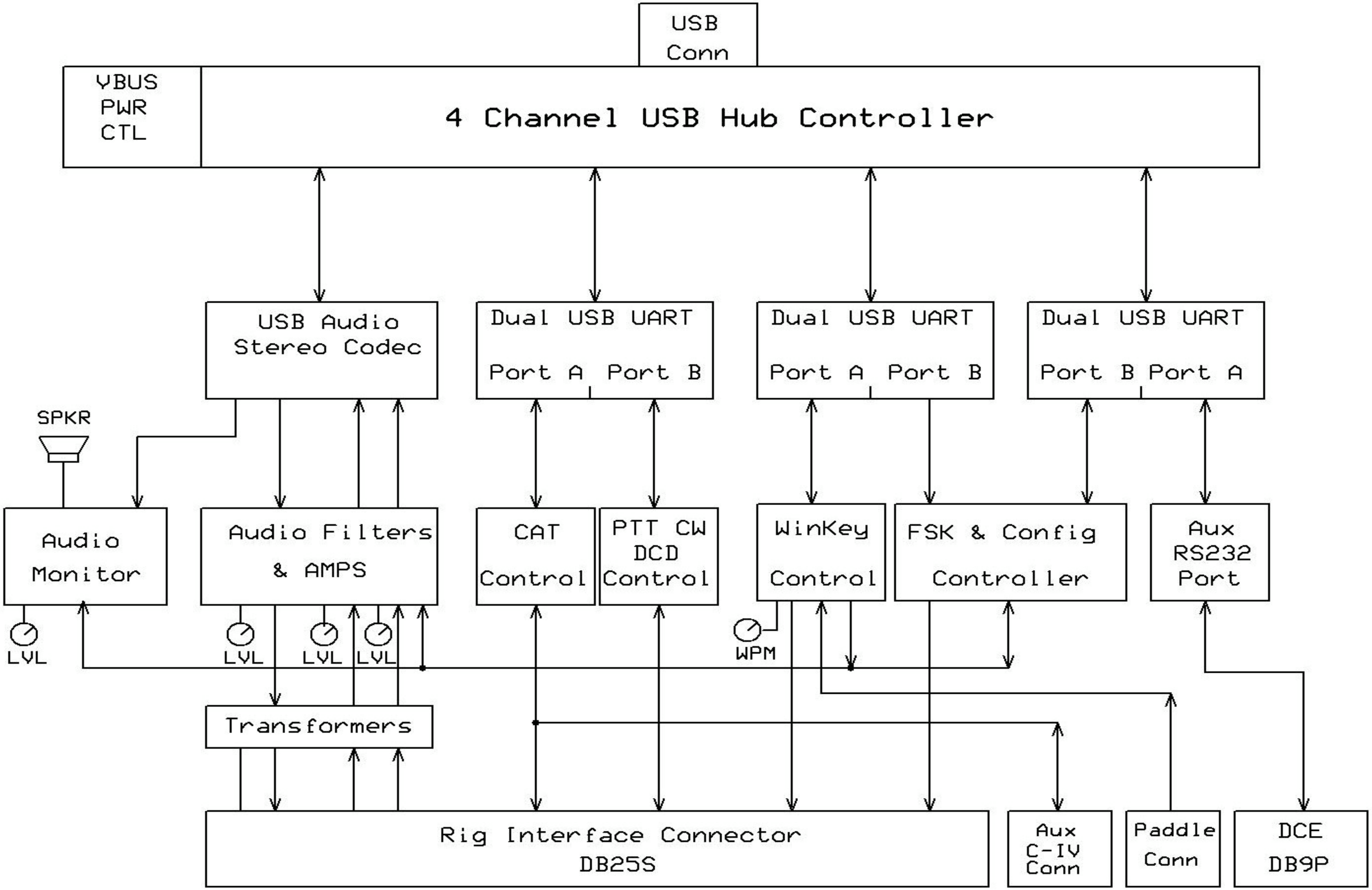
- **USB Connected & Powered**
- **Full CAT control**
- **USB Audio Codec in Interface**
- **CW Controller**
- **RTTY FSK Controller**
- **Hardware PTT control**
- **Audio Monitor**
- **Extra RS232 port**

Full Featured Interface



Full Featured Interface

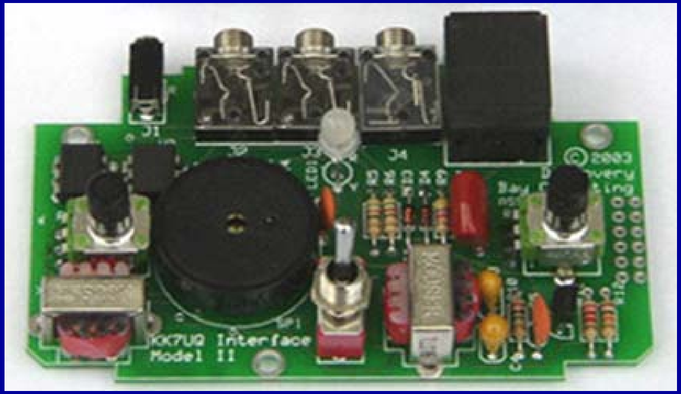


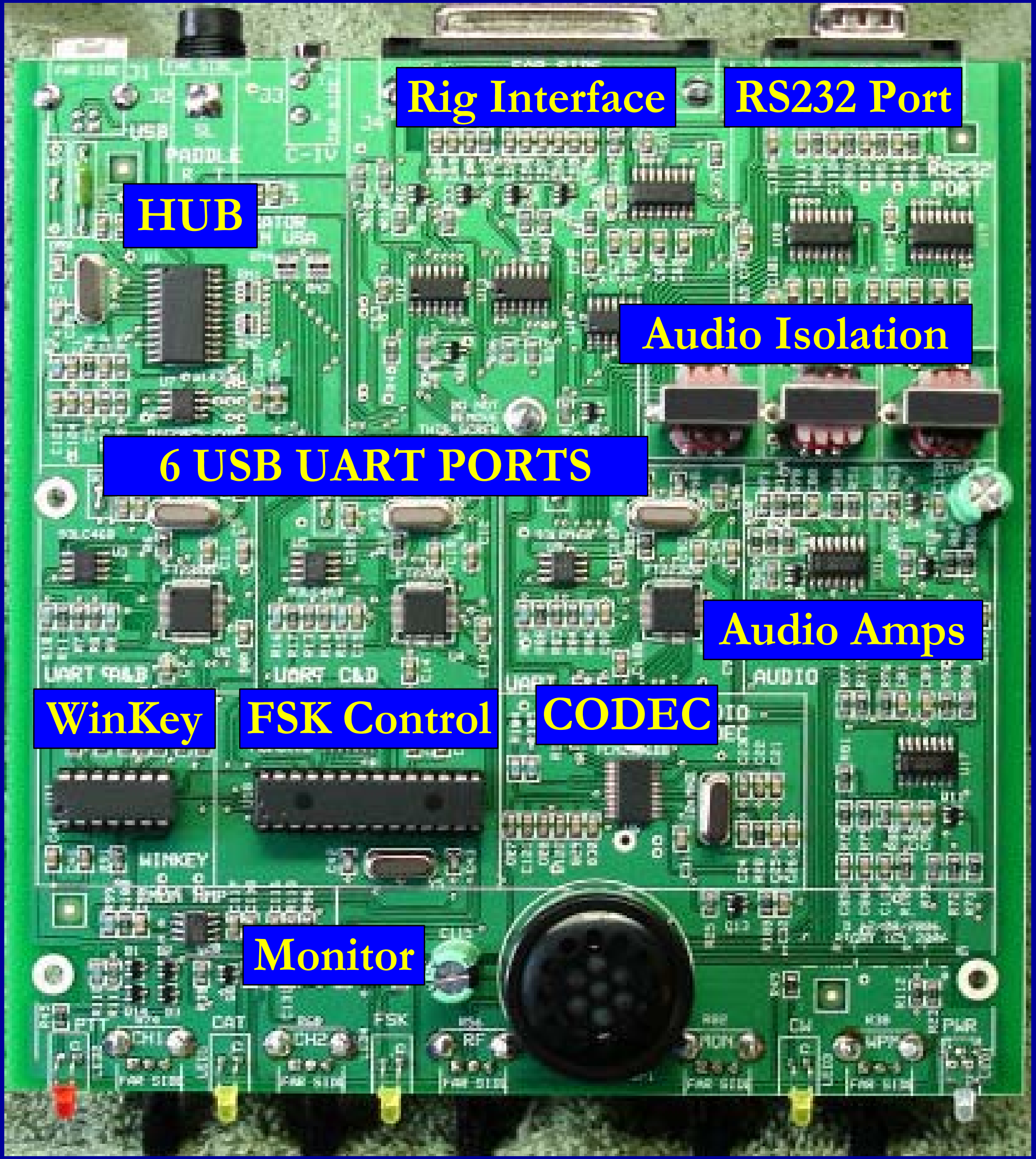


Navigator Block Diagram

Full Featured Interface vs.

Basic Interface





Sources for Full Featured Interfaces

- MFJ - several models
  - www.mfjenterprises.com
- Micro Ham
  - www.microham.com
- Rig Expert
  - www.RigExpert.com
- US Interface - Navigator
  - www.USInterface.com
- West Mountain Radio - RigBlaster
  - www.WestMountainRadio.com

Some Popular Multi Mode Software

- FLDigi - http://www.w1hkj.com/
- MultiPSK - http://f6cte.free.fr/index_anglais.htm
- Ham Radio Deluxe / DM780
  - http://forums.ham-radio.ch/
- MixW - http://www.mixw.net/
- DXLab - http://dxlabsuite.com/

More Popular Software

- Digipan - http://www.digipan.net/
- Hamscope - http://www.qsl.net/hamscope/
- WinPsk – http://www.moetronix.com/ae4jy

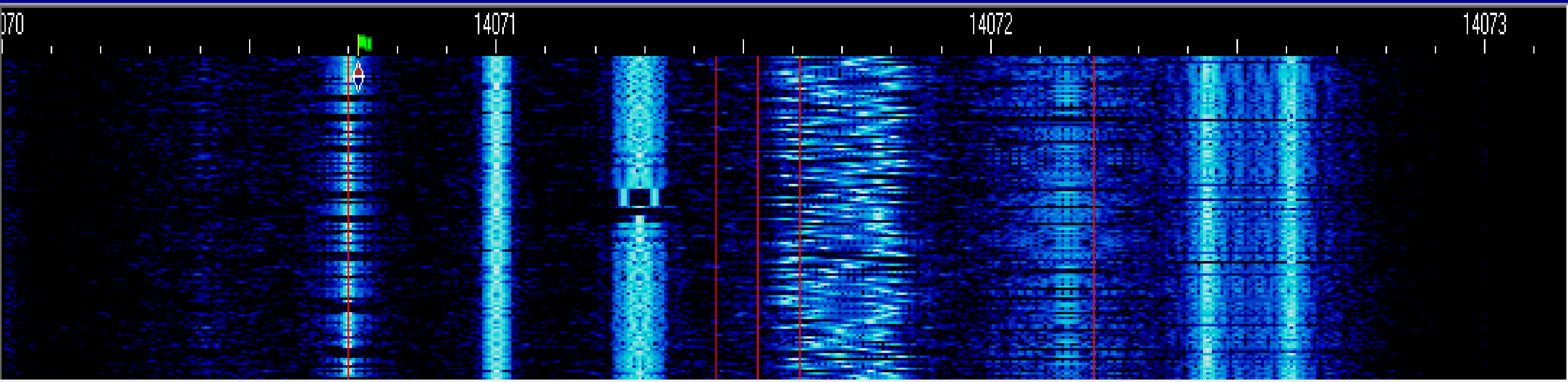
For more software, see WM2U page at:

  - http://www.qsl.net/wm2u/psk31.html

Sounds of Digital Modes

- CW BPSK31 BPSK63
- MFSK16 Hellescheiber RTTY

- All signals you hear can be copied individually Sounds of Digital Modes 🔊



MODE DISSECTION PSK-31

Thanks to KK7UQ – Clint Hurd for technical Information to follow!

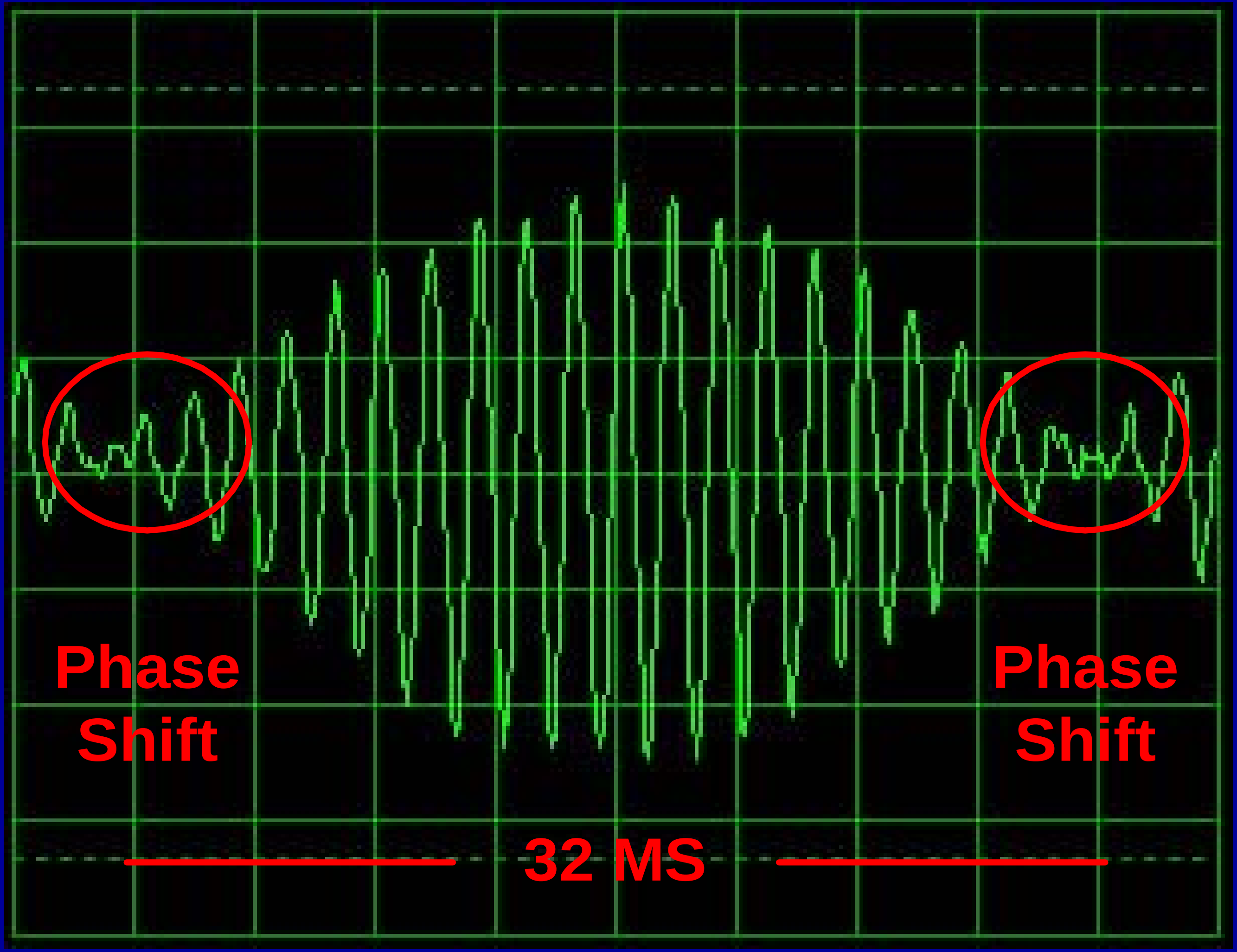
Binary Phase Shift Keying - BPSK31

- Phase modulates an audio “carrier” at 31.25 baud – audio modulates SSB transmitter
- Reverses phase 180 degrees (BPSK)
- Reduces signal level at phase shift time to reduce spurious frequencies
- Uses variable length encoding - most used characters are encoded into small word lengths

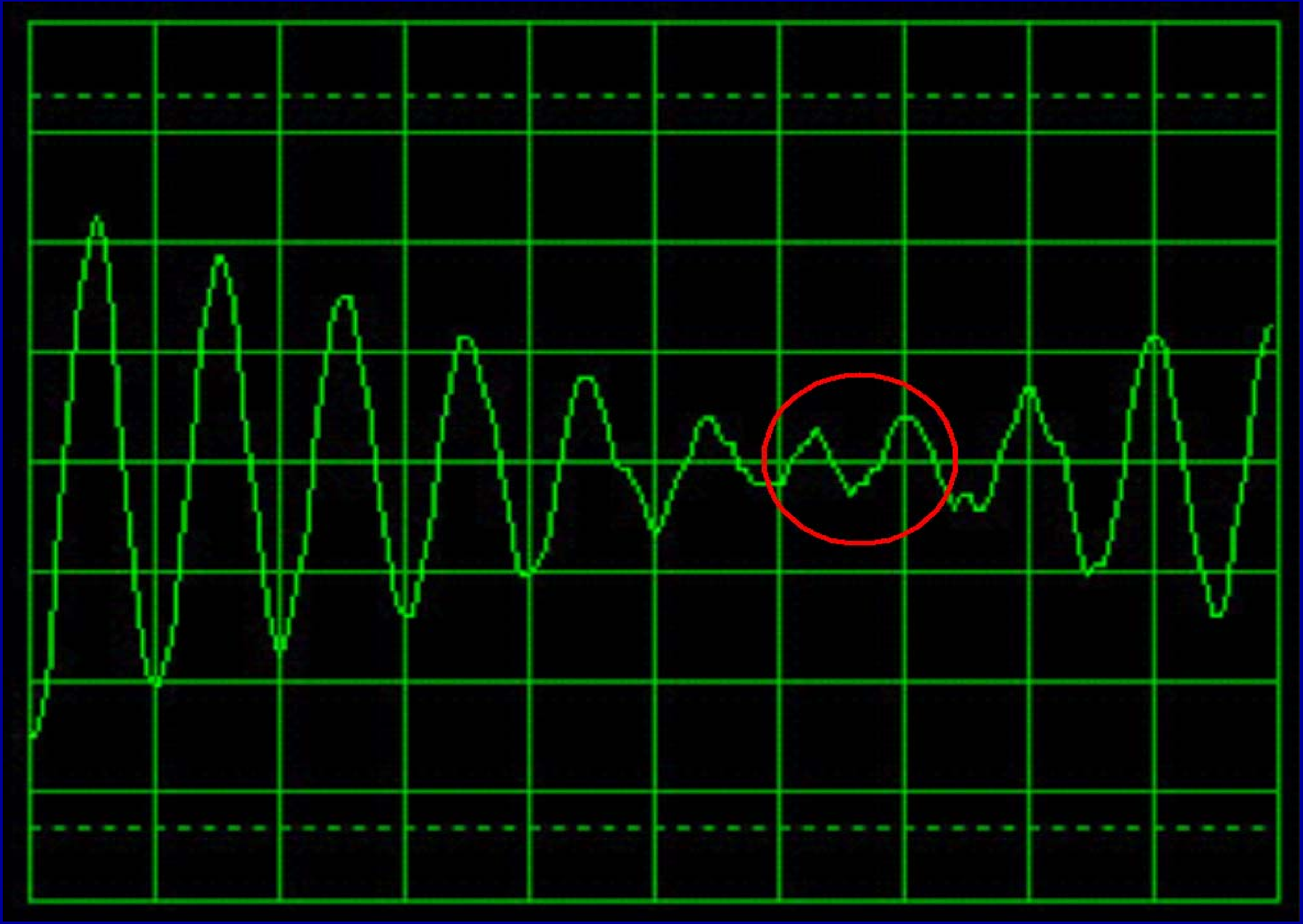
Sound of BPSK31

PSK31 Signal Coding

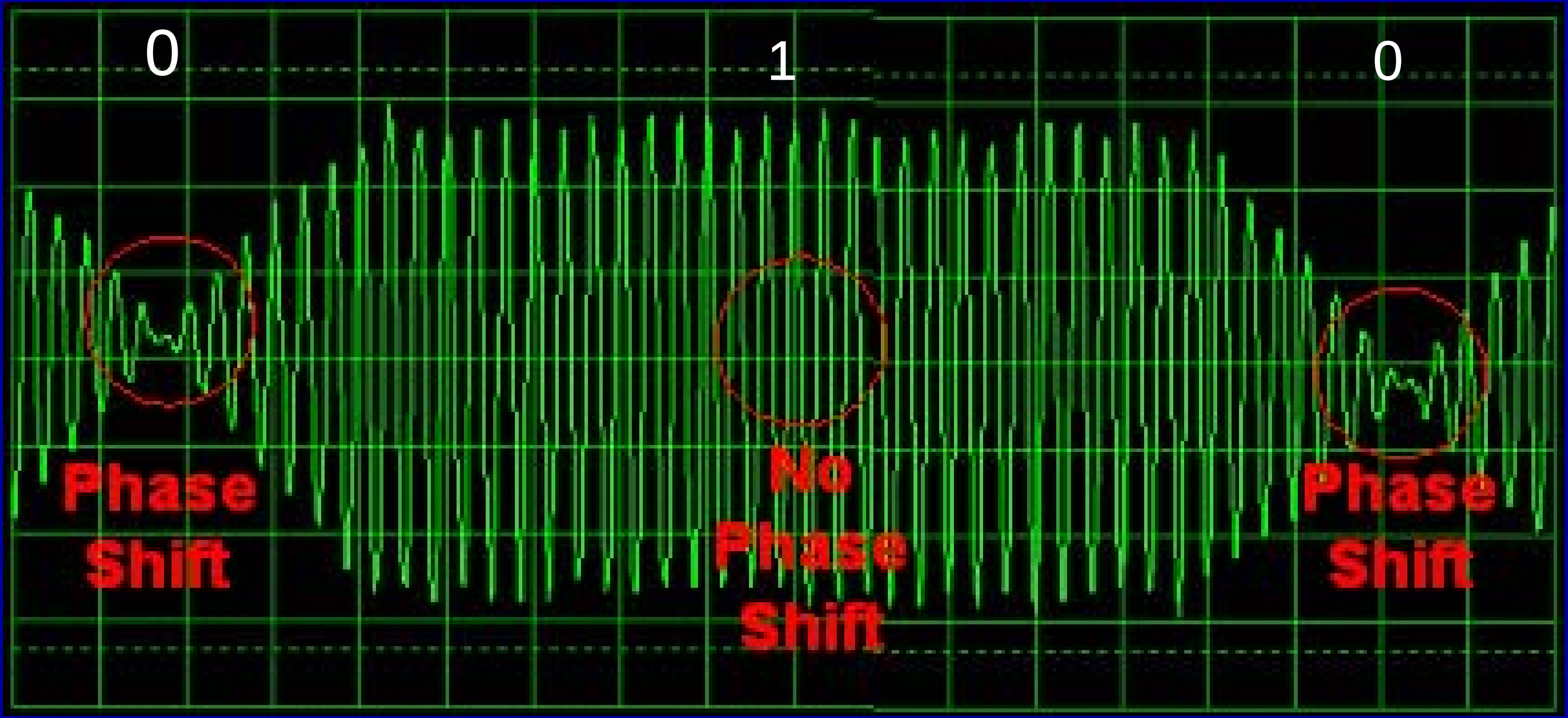
- 31.25 Baud Rate
- One Bit Time = 1/31.25 = 32 MS
- “0” Defined As Phase Change at Beginning of Bit
- “1” Defined as No Phase Change at Beginning of Bit



One BPSK31 “0” Cycle Followed by another “0”
IMD = -30dB @ Offset Freq = 700 Hz
Note: Waveform is a “two tone” signal

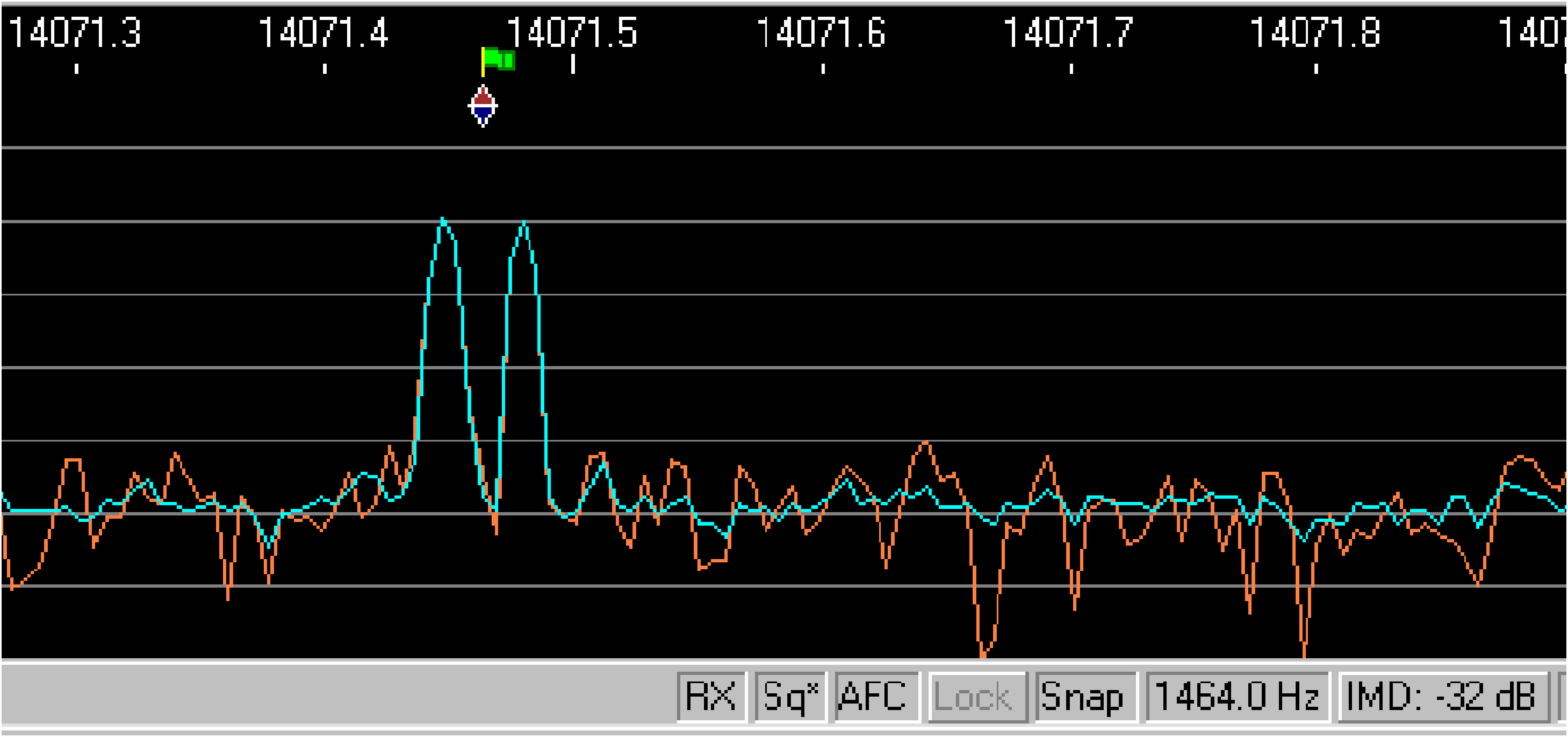


Phase Shift at Reduced Signal



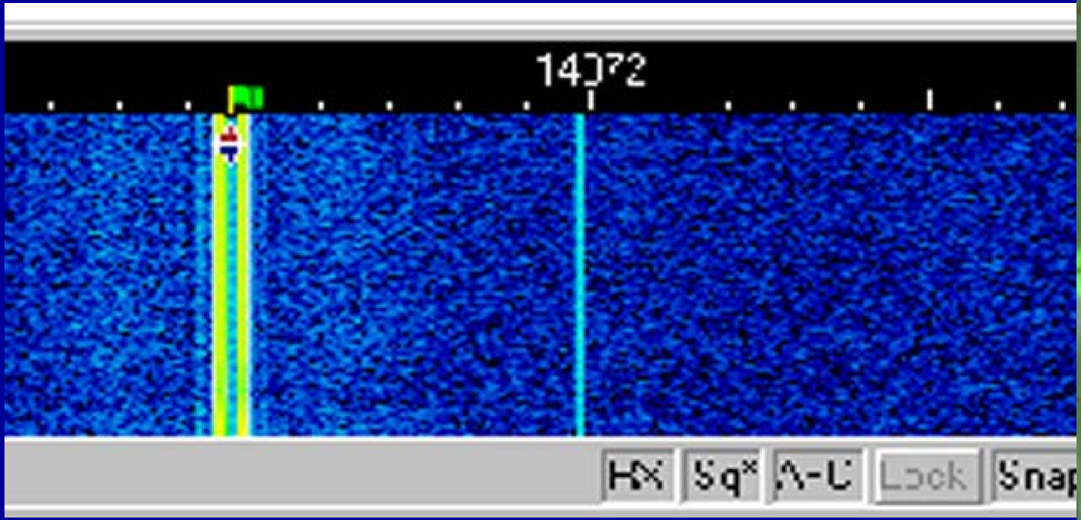
TRANSITION “010”

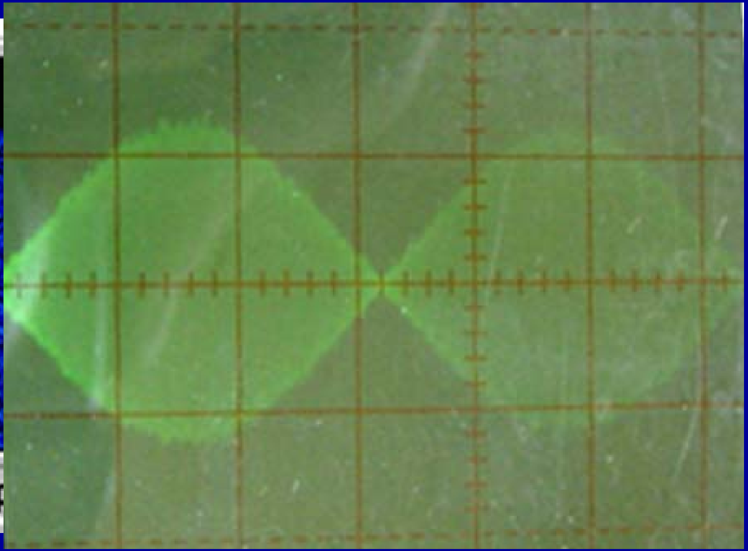
IMD -30dB

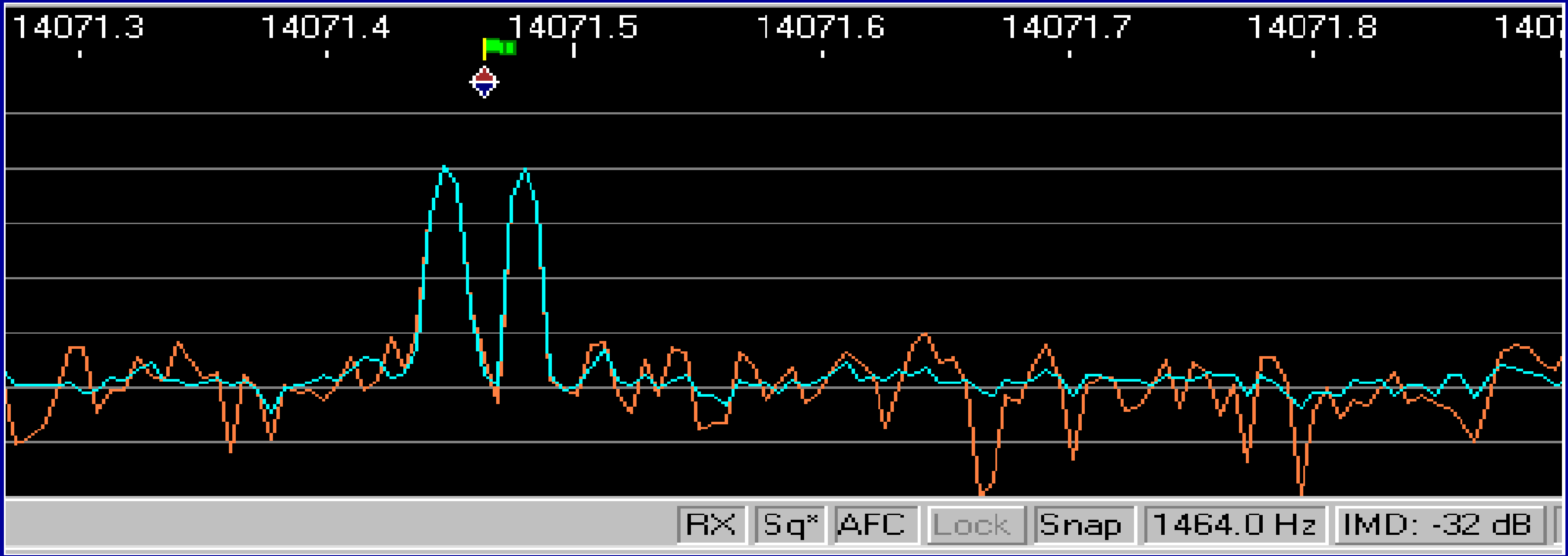


Spectrum Scan of BPSK31
Good Signal
Measured IMD -32 dB
Bandwidth 63 Hz

IMD -32 dB Good Signal



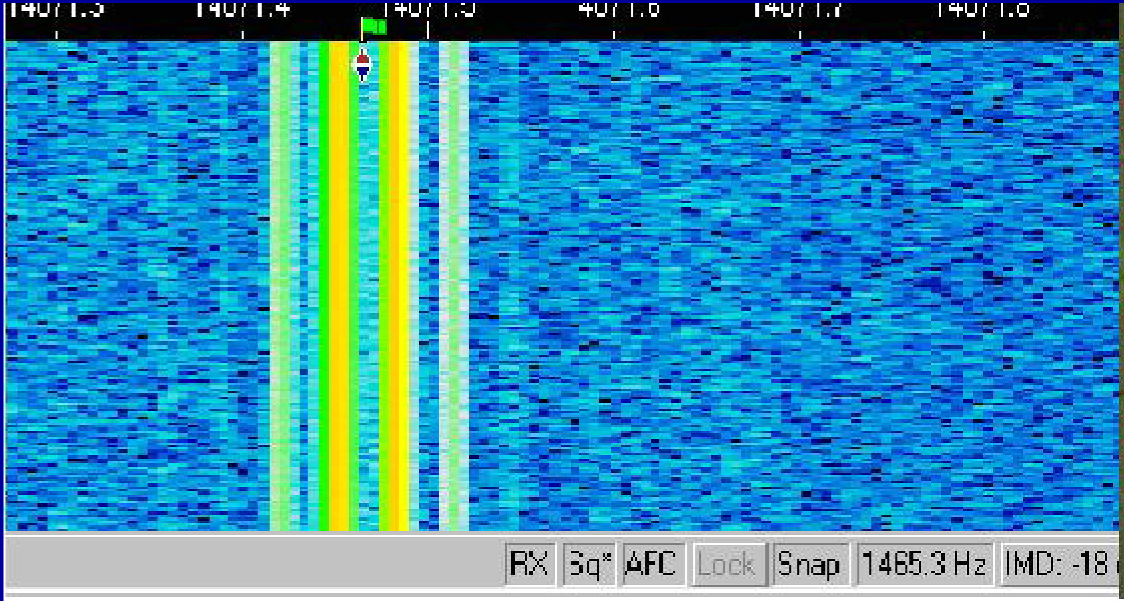




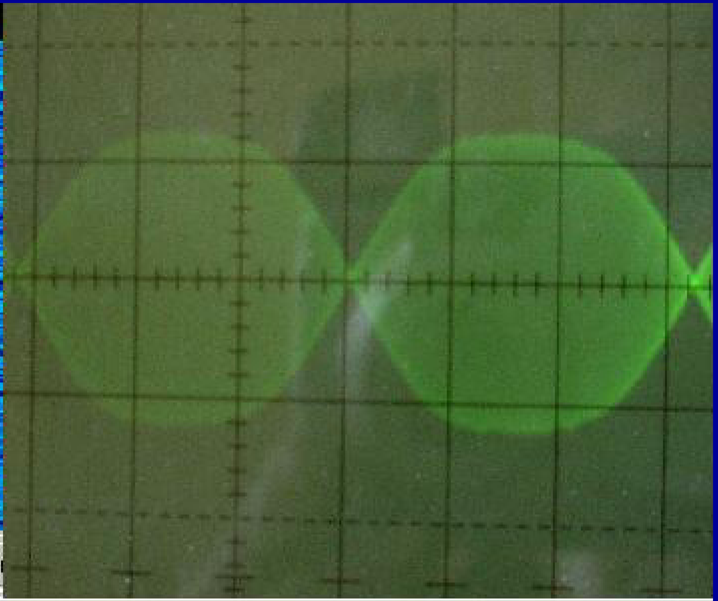
1464.0 Hz

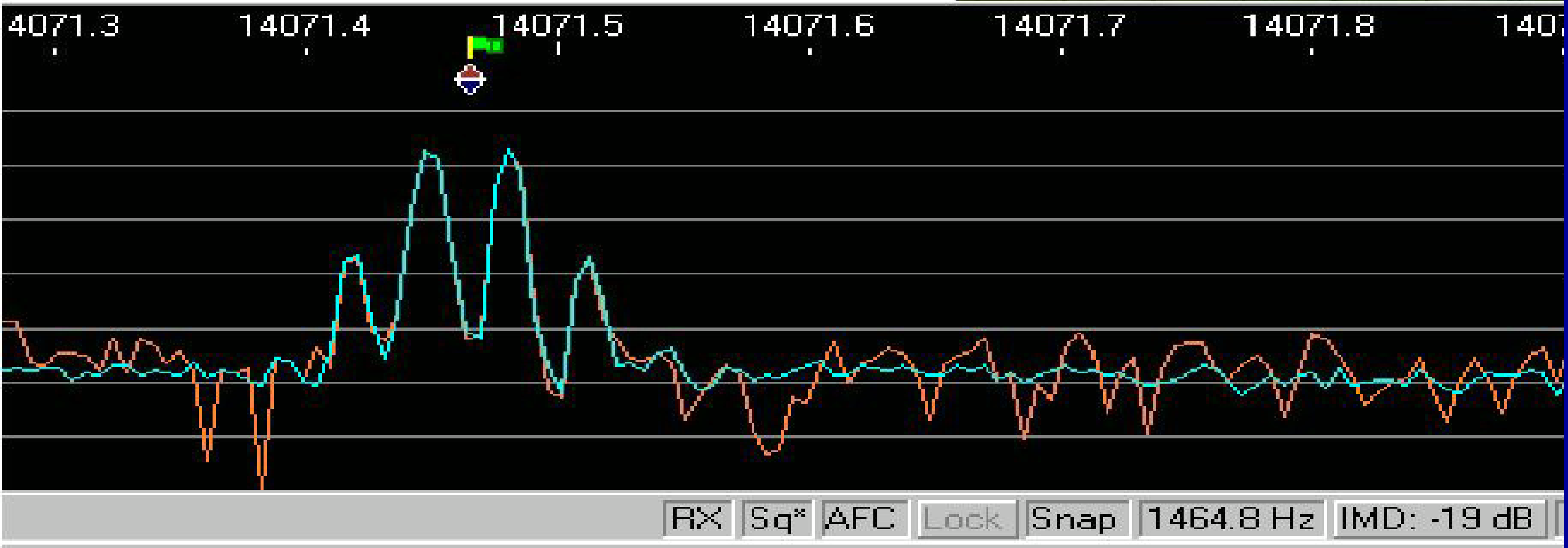
IMD: -32 dB

IMD -18dB Poor Signal



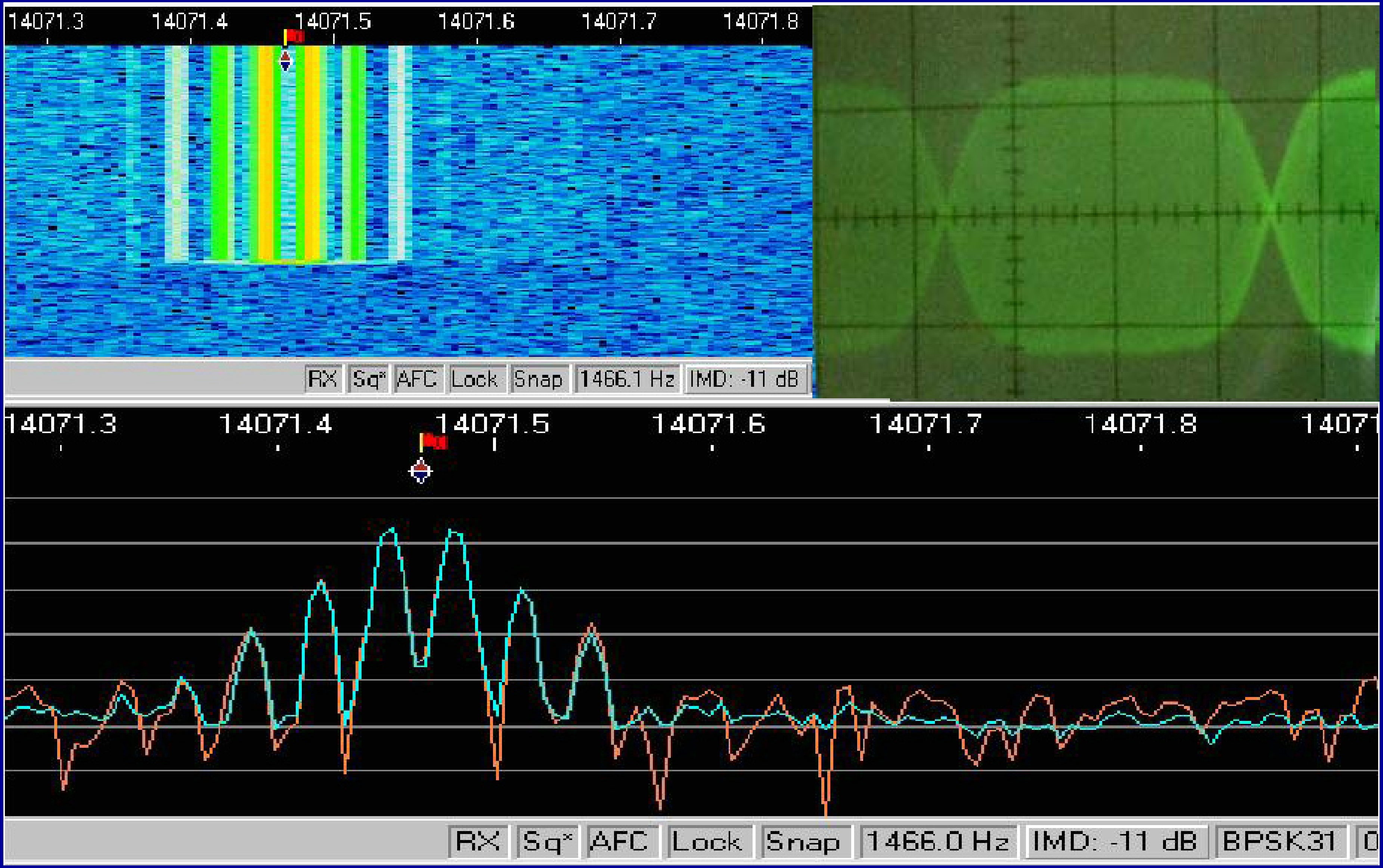
RX Sq* AFC Lock Snap 1465.3 Hz IMD: -18

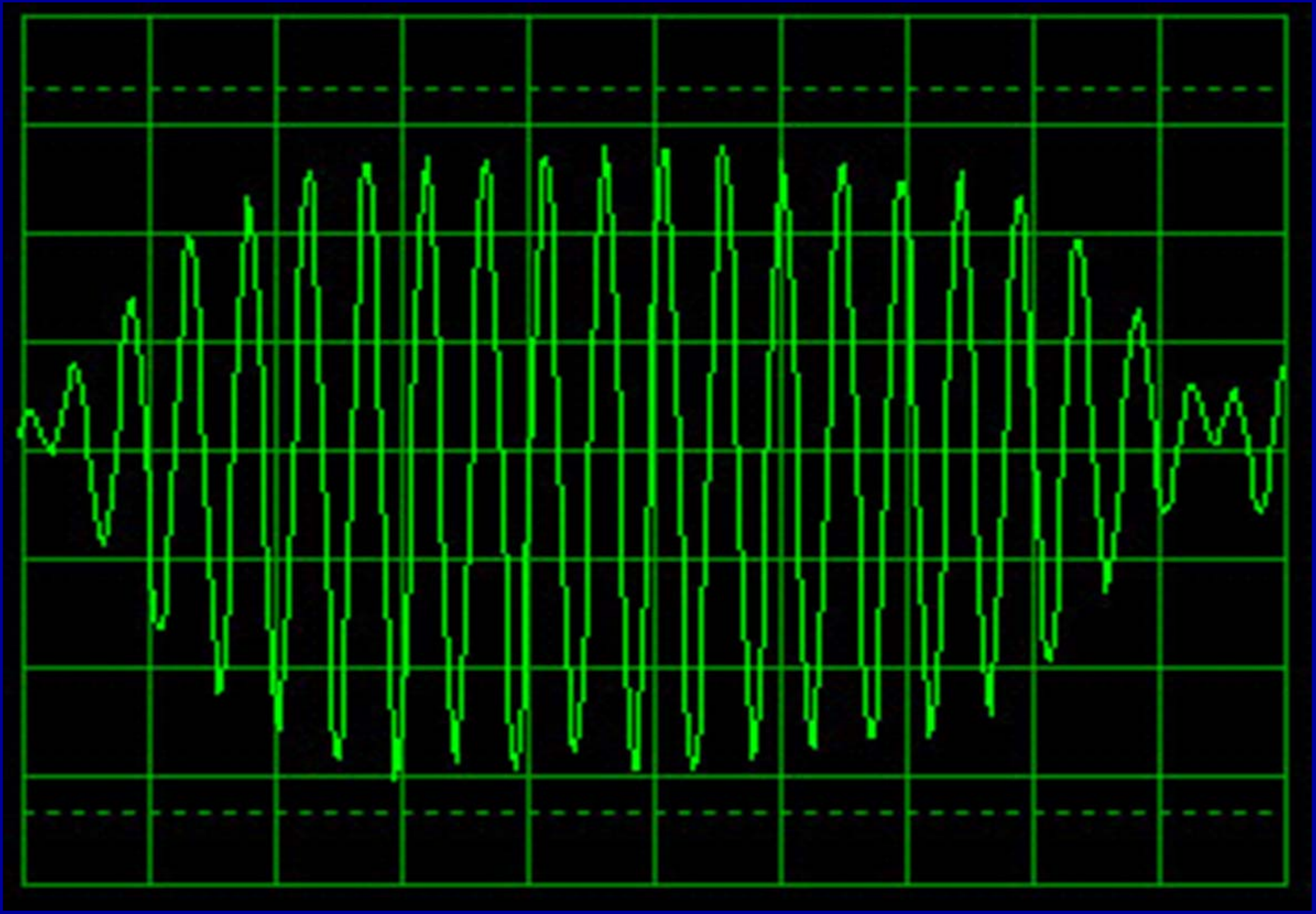




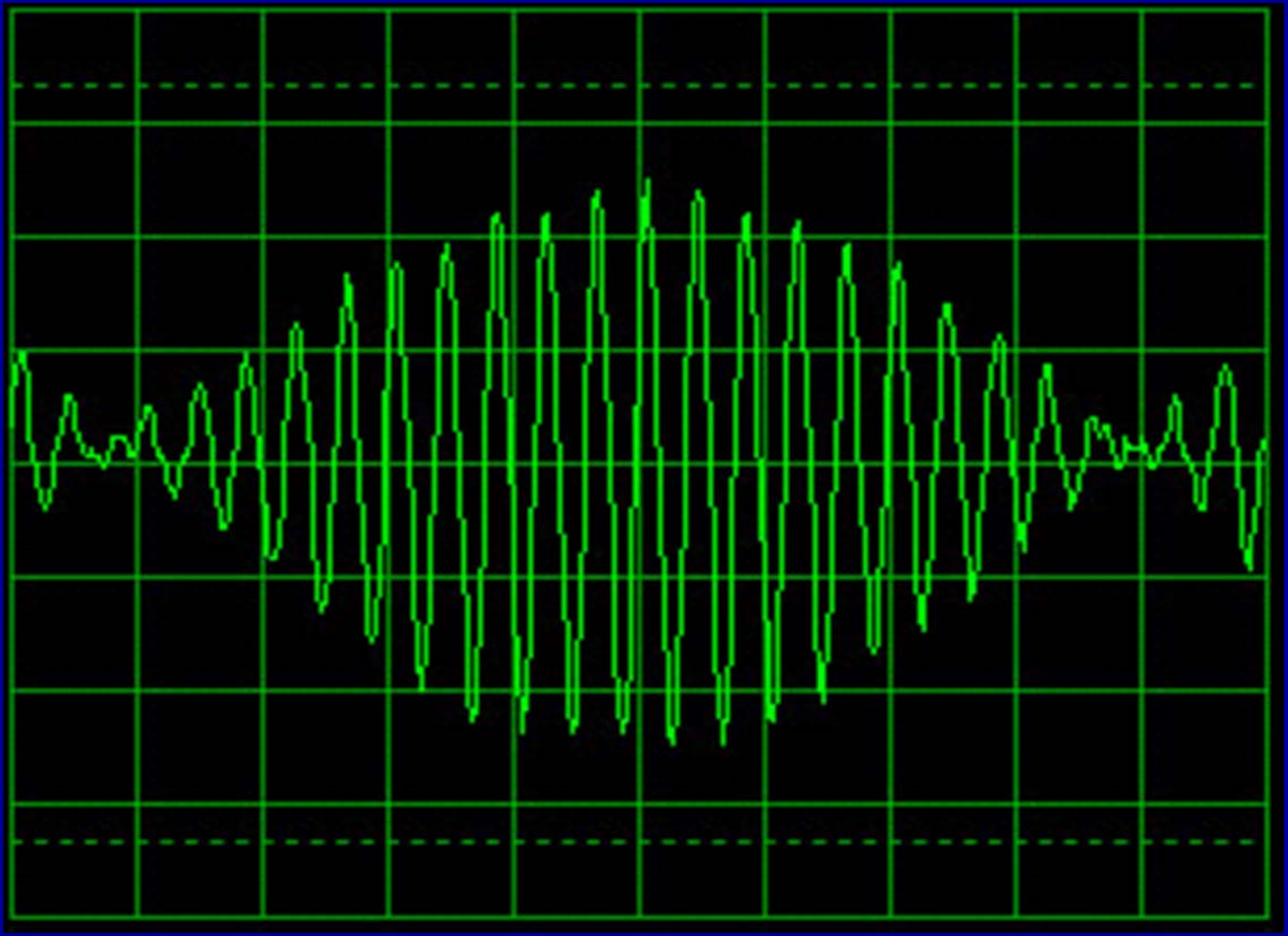
RX Sq* AFC Lock Snap 1464.8 Hz IMD: -19 dB

IMD -11dB Very Bad Signal





ONE BPSK31 CYCLE – OVERDRIVEN
IMD -11 dB



COMPARED TO A GOOD SIGNAL
AT -32 dB IMD

PSK SIGNAL BASICS

- A clean signal has unwanted 3rd order products at -24 dB or better
- Overdriving the signal may increase power output, but does NOT improve copy.

Setting the Audio Drive Level

- Adjusting the audio drive level is the proper way to set power output. (Exception: the Elecraft K3)
- You do NOT improve the signal quality of an overdriven signal by reducing the power level setting on the transceiver - you only reduce the power of an improperly adjusted signal

Audio Setup for the K3

- The Elecraft K3 has special tools to set the optimum level for sound card modes.
- Set the K3 power to 10 watts
- Set the mode to DATA / Data A
- Display the ALC meter
- Transmit a BPSK31 signal and adjust the audio drive level until you see 4 to 5 ALC bars
- Set the K3 power to 50 watts or less – this will be the peak power output

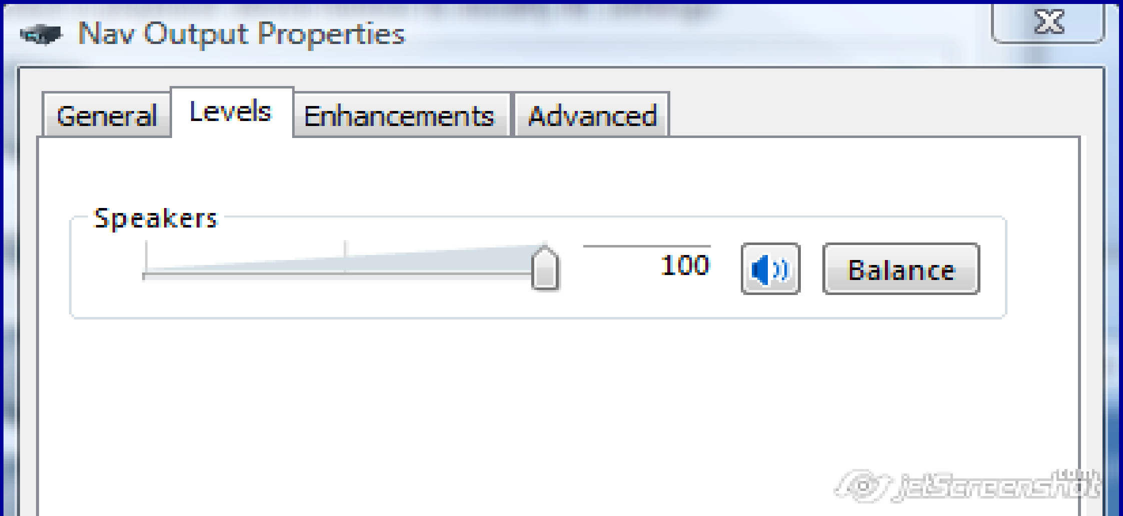
Setting the Audio Drive Level

- Adjusting the audio drive level can be done at the:
  - **PC** using the WAVE control slider
  - **Interface** if you have a level control pot
  - **Transceiver** Mic. Gain

PC Output Audio Control

-Use the Windows Control Panel / Sounds to set the level for the output sound function

-If your interface has output level control, set the sound card to 100% otherwise & use the level control to set the power level.



Speakers 100

Transceiver Mic. Gain

- The transceiver Mic. gain can also be used to control audio drive level.

- Normally this is set for proper phone audio level and left alone when using PSK.

How Much Power?

- Protect your transceiver finals - normally run at no more than 50% of rated CW output (peak)

- Turn off Compression

- Run with minimum ALC (Except K3)

Conservative Method

- Pick a waterfall frequency in the middle of your rig output filter - typically 1200 Hz
- Set your rig power control to 100%
- Turn off Compression
- Transmit an IDLE signal (no typing, buffer empty)
- Adjust audio drive level to produce an output of 30% (ave) or 50% (peak) of rated CW output.
- ALC should be at low or zero level

Why De-Rate Power So Much?

- The PSK signal will run at 60% duty cycle when in IDLE, and up to 90% when transmitting data.
- The transceiver audio path must stay linear (no or little ALC or Compression).
- Other digital modes run at near 100% duty cycle

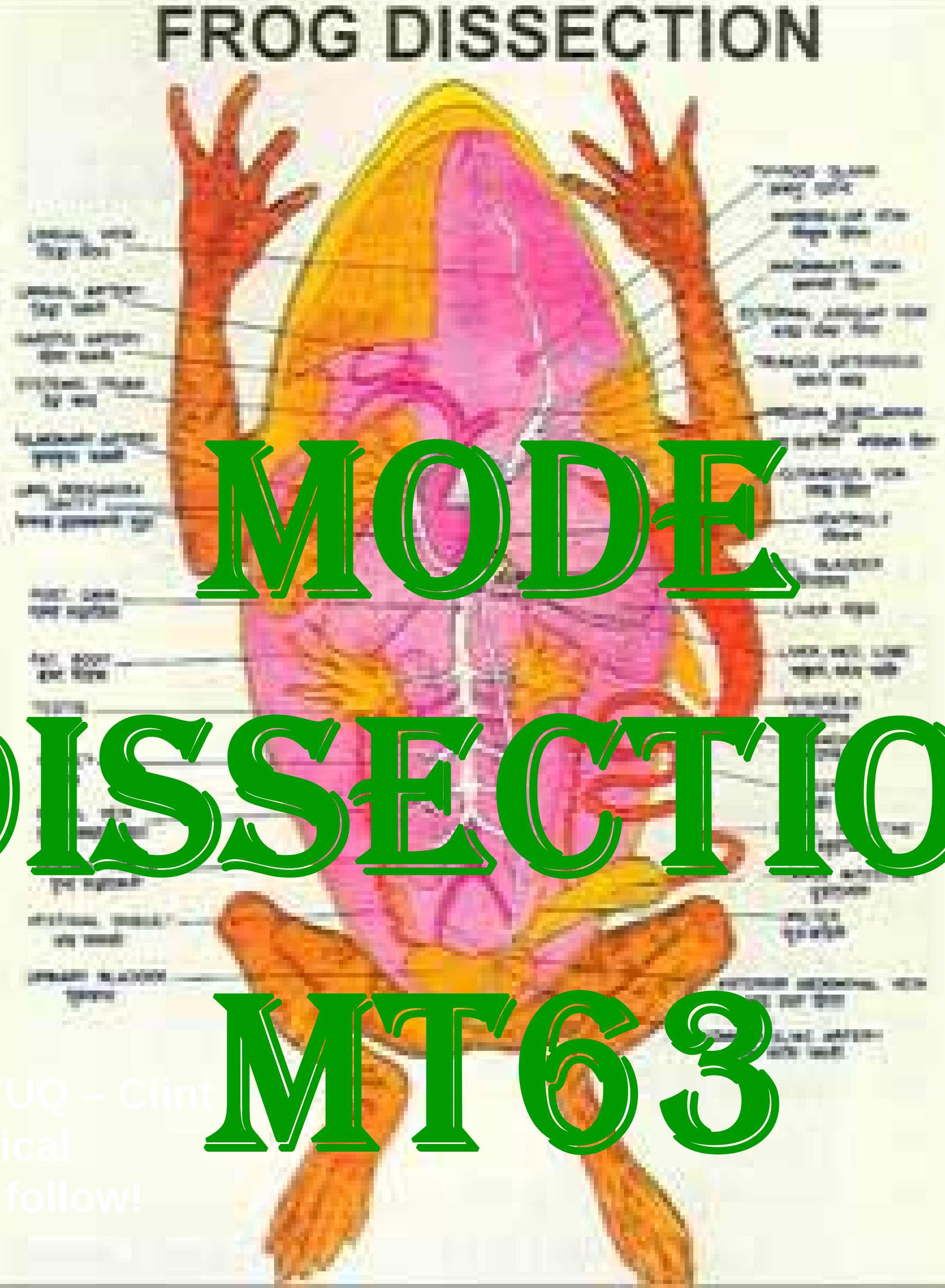
Advanced Modes

MT63

DominoEX

Olivia

MFSK16



MODE DISSECTION MT63

Thanks to KK7UQ – Clint Hurd for technical Information to follow!

MT63

Designed by Pawel Jalocha SP9VRC

- Not often found on Ham HF bands
- Used extensively in MARS HF bands
- Used on VHF
- Supported by
  - FLDIGI
  - Ham Radio Deluxe / DM780
  - MixW (2.16 or later)
  - MultiPSK

MT63 - Features

- 64 Different, Simultaneous Modulated Tones
- Up to 32 Tones FSK
- Bandwidth up to 2000 Hz Wide
- Uses Forward Error Correction (FEC)
- Data rate consistent with that of an average typist – about 24 WPM
- FEC buffer up to 12.8 seconds delay
- Superior performance with poor S/N
- Easy to tune 100 to 250 Hz (but hard to see)

MT63 Advantages

- High bandwidth data channel – 100 WPM
- Excellent FEC
- Baud rate of individual channels is low
- Immune to Jamming
- Well suited to transfer of large blocks of data

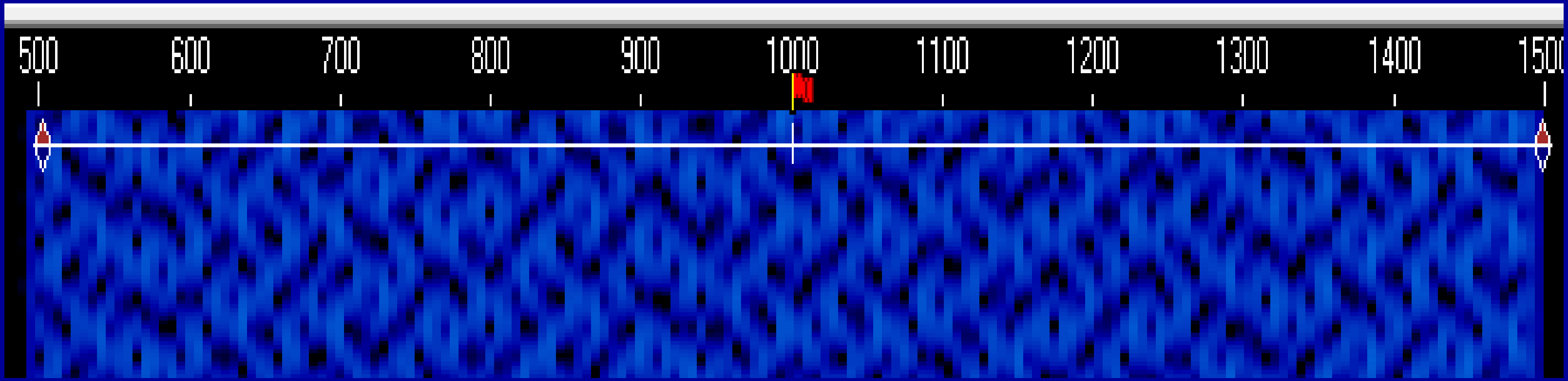
MT63 Disadvantages

- High bandwidth usage
- Latency
  - Can take 15 seconds for data to appear
  - Not well suited to keyboard conversational operation
- Interferes with other users of the channel
- Audio sampling rate of Transmitter and receiver need to be adjusted to be close

MT63 Specs

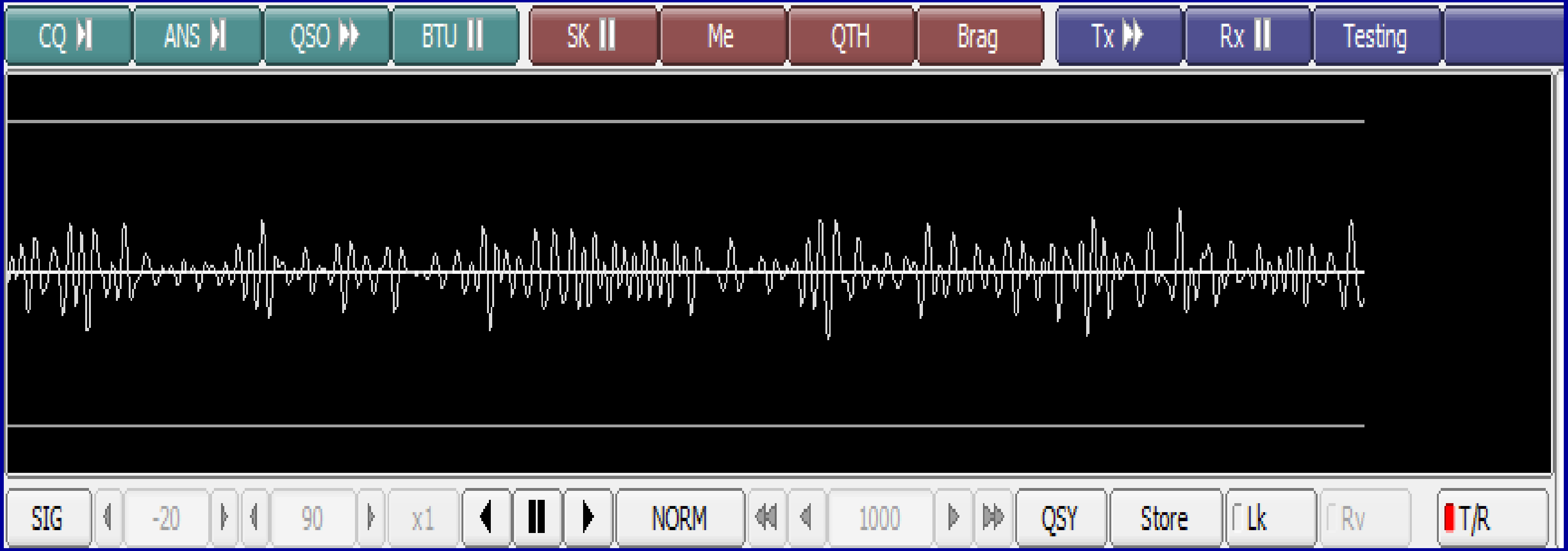
Mode	Symbol Rate Baud	Typing Speed WPM	Bandwidth Hz .
MT63-500	5	50	500
MT63-1000	10	100	1000
MT53-2000	20	200	2000

MT63 – Waterfall View

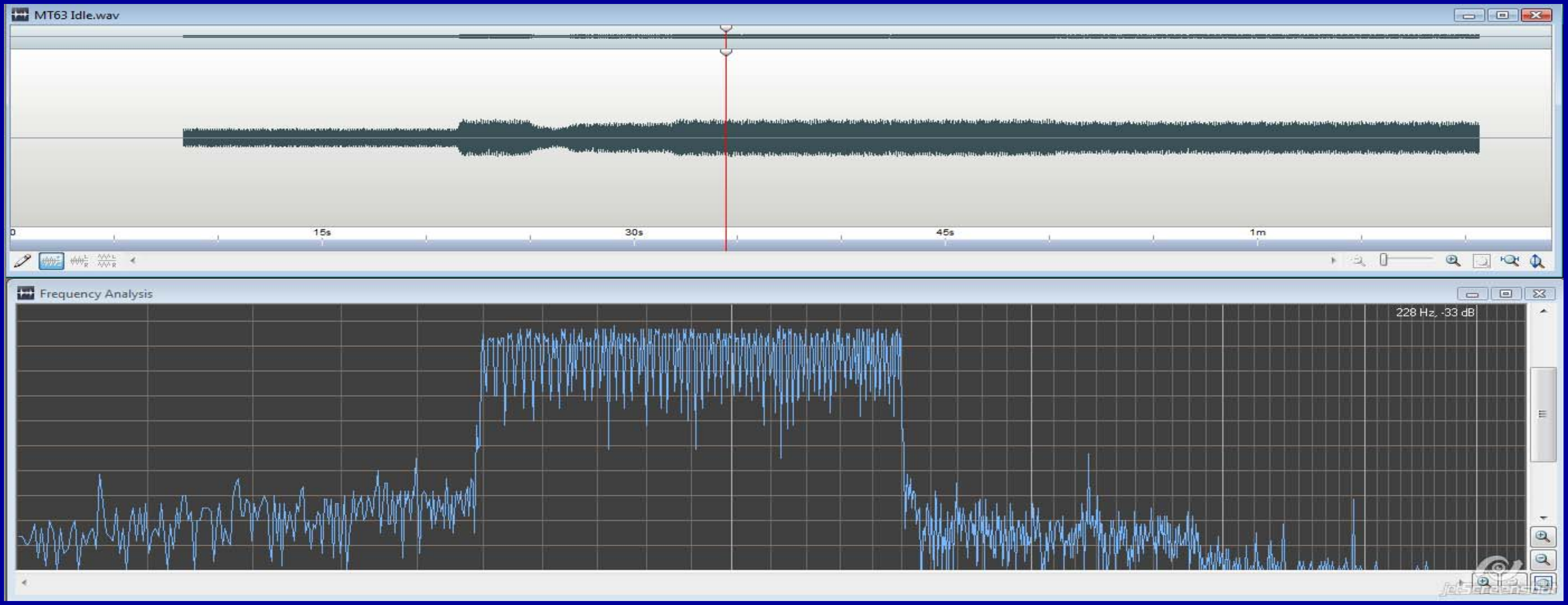


Above is a view of the signal being transmitted - the received signal never looks this good!

MT63 Realtime View



MT63 Spectrum View



MT63 - Tuning

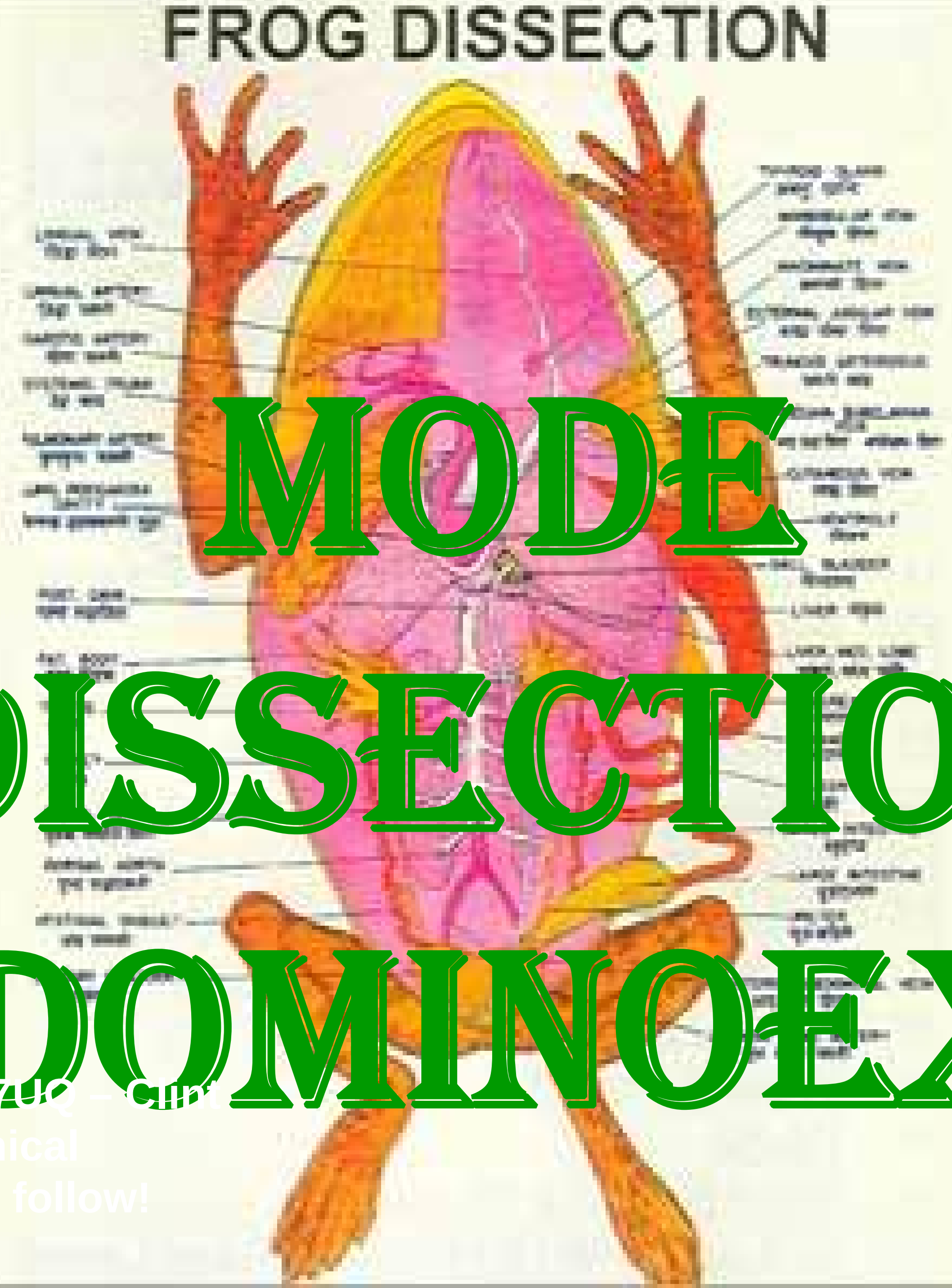
- Setup your audio drive level for a clean signal of BPSK31 at max 50 W peak
- Leave the settings alone when you switch to MT63 – the software is scaled to not exceed 100% of the audio drive

MT63 Receive Tuning

- Signal is often hard to see on the waterfall unless the signal is fairly strong
- Set your rig dial frequency to a pre-agreed frequency
- Usually, the center of the signal is set to
  - 750 for MT63-500
  - 1000 for MT63-1000
  - 1500 for MT 63-2000

MT63

- Demo of MT63



MODE DISSECTION DOMINOEX

Thanks to KK7UQ – Clint Hurd for technical Information to follow!

DominoEX

- Designed by Con Waissilieff ZL2AFP and Murray Greenman ZL2BPU
- Supported by
  - FLDIGI
  - Ham Radio Deluxe / DM780

DominoEX – Features

- Incremental Multi Frequency Shift Keying (IFK)
  - Change in tone position determines the 4 bit value of a symbol
  - Offset algorithm ensures no sequential tones are the same, or adjacent
  - Improved resistance to multi-path and Doppler effects
- 18 Tone Frequencies
- Bandwidth up to 524 Hz Wide

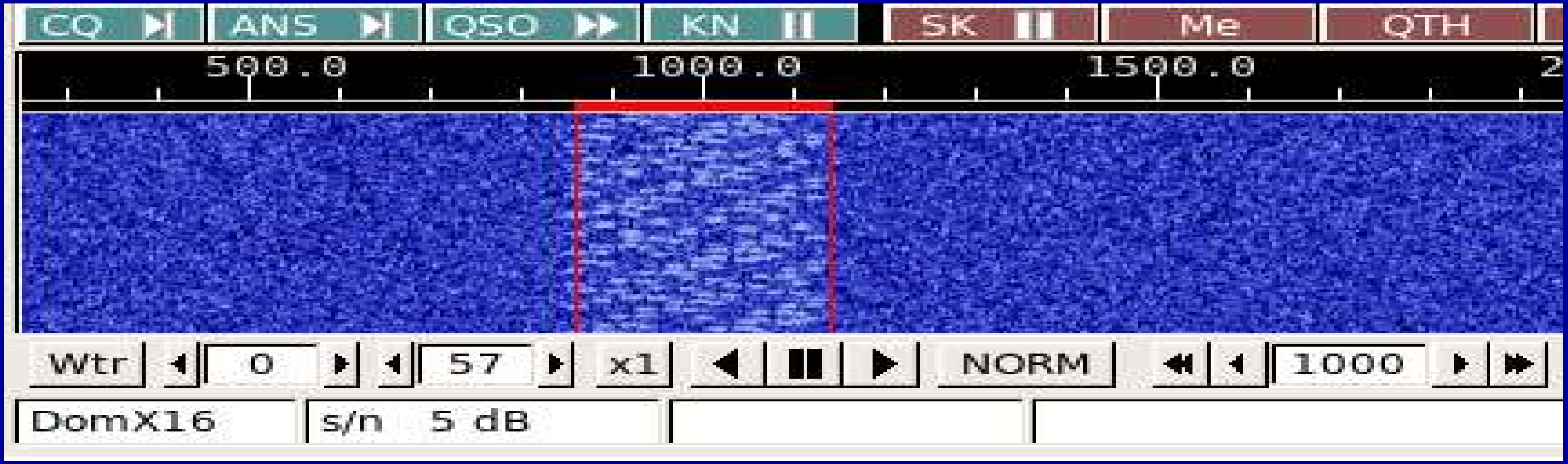
DominoEX Features

- Optional Forward Error Correction (FEC)
- Data rates from 29 to 160 WPM
- Superior performance with poor S/N
- DominoEX11 optimized for HT NVIS on 80M at night
- Not bothered by Polar Flutter

Domino Specs

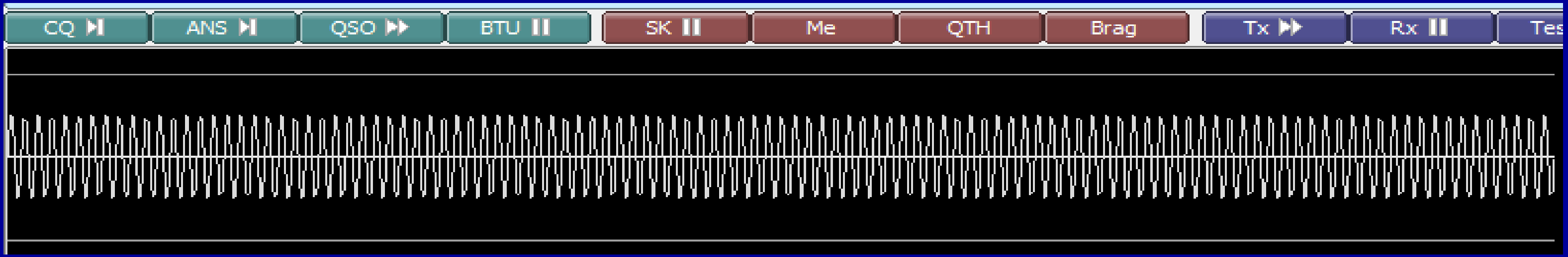
Mode	Baud	WPM	BW	Tone Spacing
DominoEX4	3.9	29	173 Hz	7.8 Hz
DominoEX5	5.4	44	244 Hz	10.8 Hz
DominoEX8	7.8	58	346 Hz	15.6 Hz
DominoEX11	10.8	80	262 Hz	10.8 Hz
DominoEX16	15.6	115	355 Hz	15.6 Hz
DominoEX22	21.5	160	524 Hz	21.5 Hz

Domino Signals



DomX16

s/n 5 dB



Domino Robustness Example

- **Recent high altitude balloon experiment by Middle School Radio Club in Mississippi used DominoEX16 for the telemetry. 1 watt, 20 Meter transmitter 14.081.500 mHz**
- **Copied at Port Townsend WA by KK7UQ**
- **$$KC5NXD,128,16:53:00,3233.85,-08903.11,24430,10,8.38,-17*40**
  - **Alt 80.1k ft Temp -17C Voltage 8.38V**

DominoEX22

- Demo of DominoEX22

Olivia

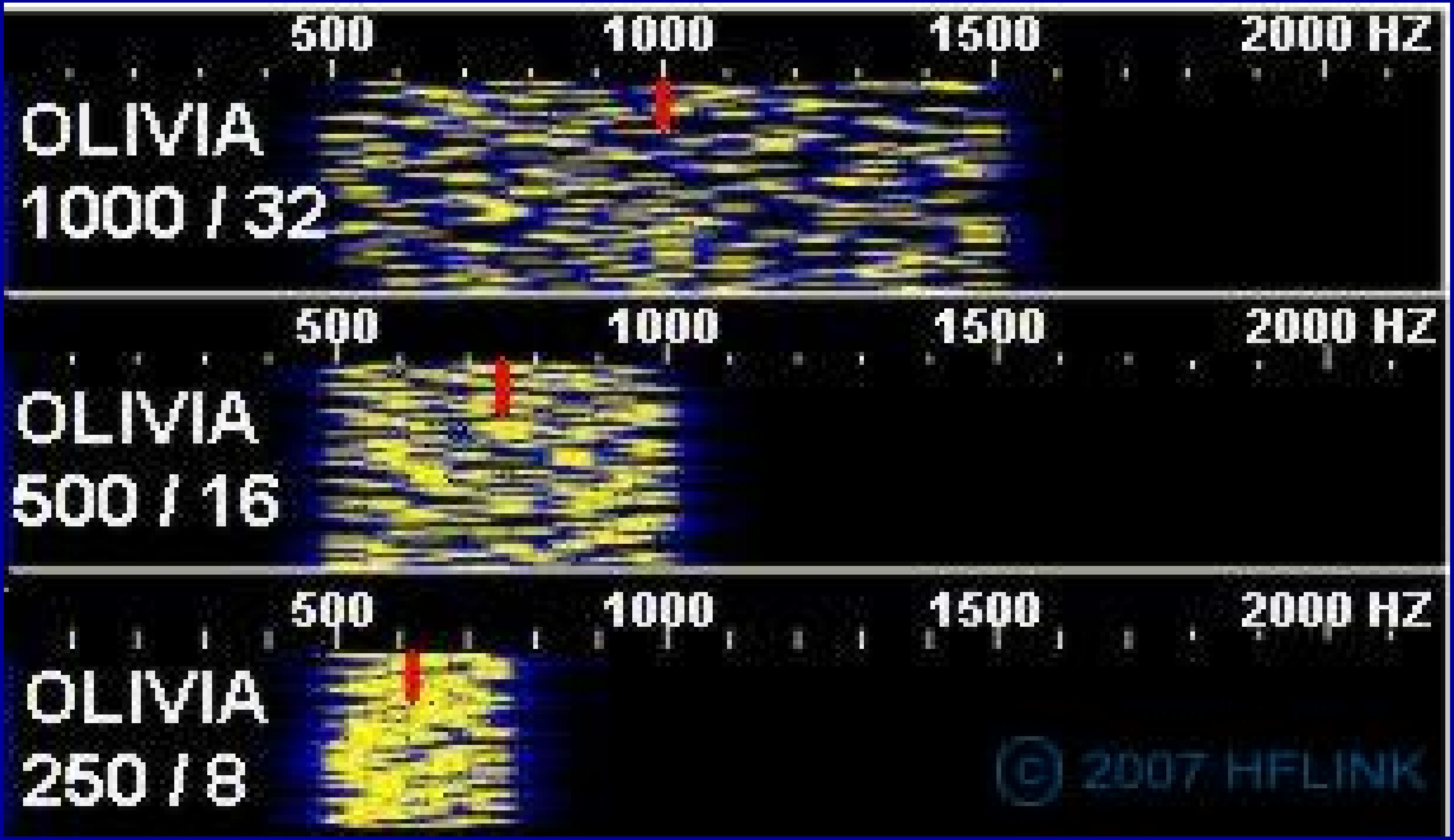
Designed by Pawel Jalocha SP9VRC

- Look for signals just above the HF PSK areas.
  - Example: 14.073 to 14.074 MHz
- Supported by
  - FLDIGI
  - Ham Radio Deluxe / DM780
  - MixW (2.16 or later)
  - MultiPSK

Olivia – Features

- Multiple Frequency Shift Keying
- Up to 32 Tones FSK
- Bandwidth up to 1000 Hz Wide
- Uses Forward Error Correction (FEC)
- Data rate consistent with that of an average typist – about 24 WPM
- FEC buffer about 5 seconds delay
- Superior performance with poor S/N
- Not bothered by Polar Flutter

Olivia Waterfall Patterns



Olivia Specs

Mode	Baud	WPM	BW	S/N copy level	
Olivia 250 / 8	31.25	14.6	250	-14 dB	
Olivia 500 / 8	62.5	29.2	500	-13 dB	
Olivia 500/16	31.25	19.5	500	-13 dB	
Olivia 1000/32	31.25	24.4	1000	-12 dB	*

* Default calling rate

Tuning Olivia

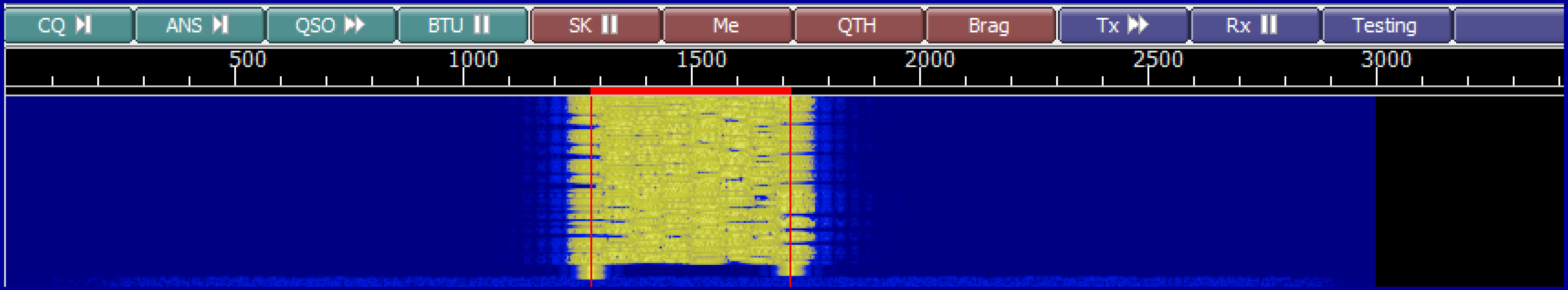
- Tone spacing: 15.33 Hz
- Bandwidth: 230 Hz
- Must find center of signal within 15 Hz
- Use “Sound History” & AFC feature of MixW to lock on to signal

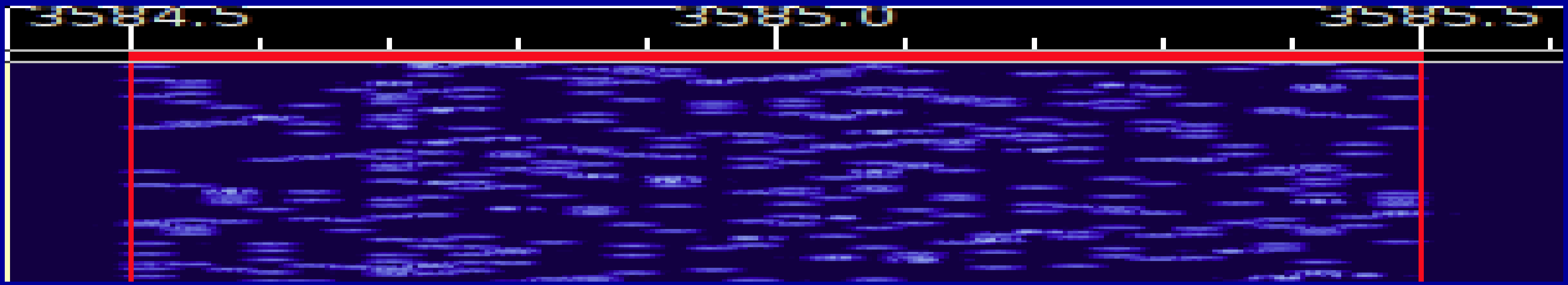
Olivia Tuning

Set the tuning guides over the edges of the signal

Turn AFC ON

Once Receive is established, Turn LOCK (Lk) ON





Olivia

- Real time demonstration

MODE DISSECTION MFSK16

Thanks to KK7UQ – Clint Hurd for technical Information to follow!

MFSK16

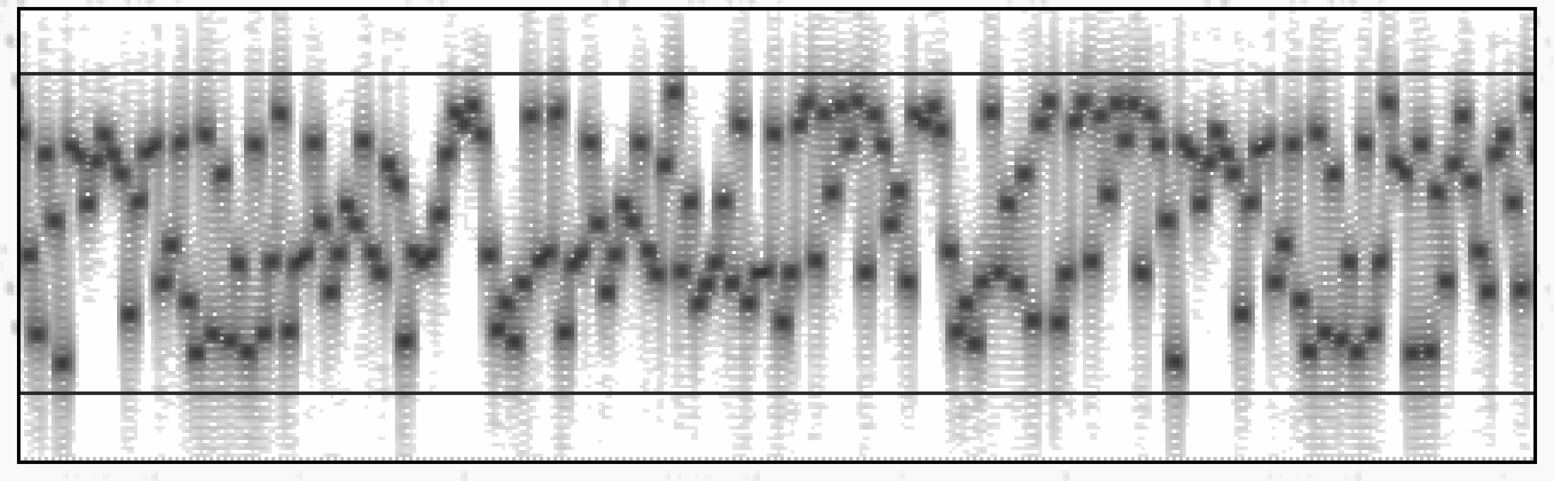
- Multiple Frequency Shift Keying 16 Baud
- 16 Tones FSK
- Four bits per tone
- 250 Hz Wide
- Uses Forward Error Correction (FEC)
- Uses Varicode to optimize throughput
- Data rate consistent with that of a fast typist – about 58 WPM
- FEC buffer about 5 seconds

MFSK16

- Adv: Very good performance on long path contacts and over polar routes
- Disadv: Wider bandwidth, harder to tune, needs stable TX/RX
- Sounds of MFSK16

MFSK16 Spectrogram

Spectrogram of MFSK16 signal over 20 seconds of transmission. Horizonal lines are at 1000 Hz and 1300 Hz. Contains about 120 characters raw rate, 60 characters effective rate (FEC used).



Tuning MFSK16

- Tone spacing: 15.33 Hz
- Bandwidth: 230 Hz
- Must find center of signal within 15 Hz
- Use “Sound History” & AFC feature of MixW to lock on to signal

MFSK16

- Demo of MFSK16

END

Appendix

- Discussion of IMD

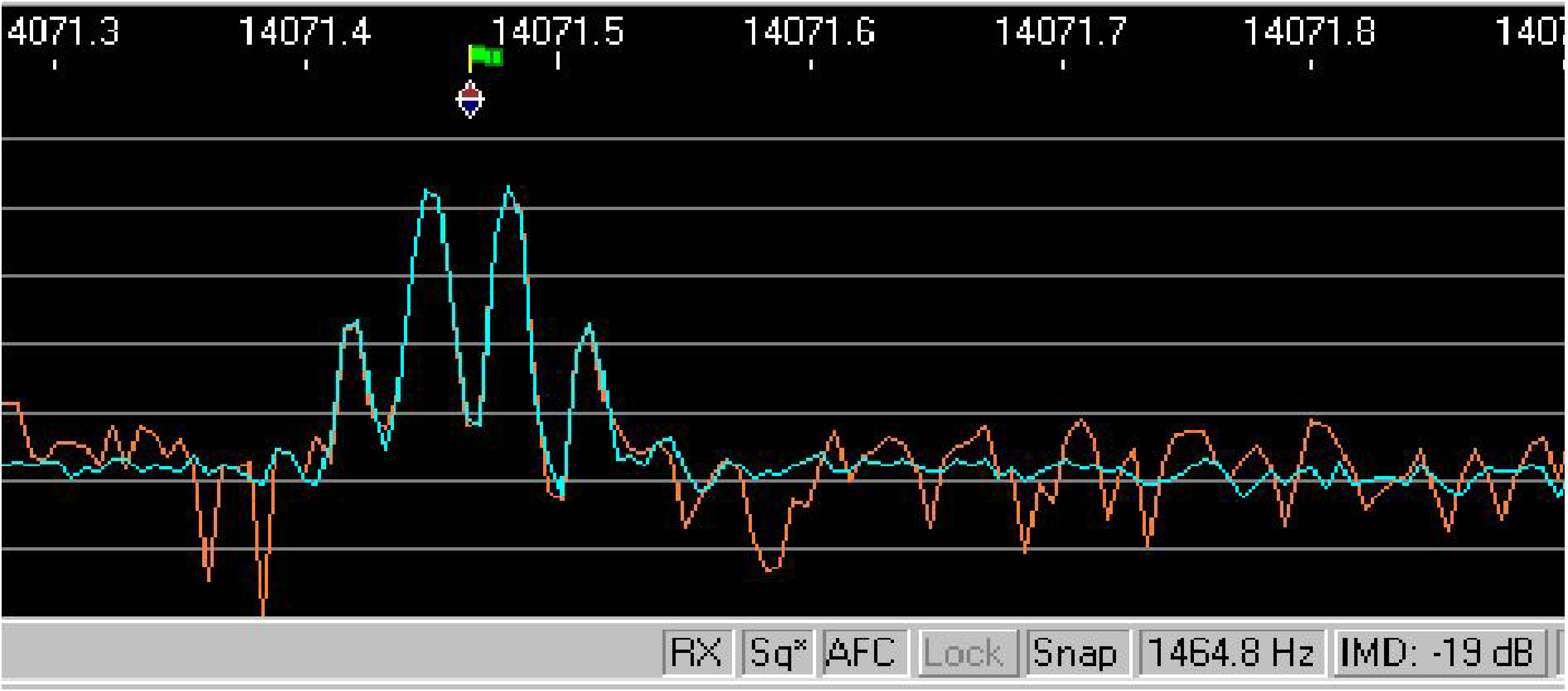
IMD

- What is IMD?
- Giving an IMD Report
- Things to look out for
- Take the IMD with a grain of salt
- Let your eye be your guide

What is IMD?

- IMD - InterModulation Distortion
- Measures “linearity” of audio path of the PSK signal through the transmitter and the receiver
- A software tool built into most PSK software

IMD Measurement



The strength of the primary signal compared to the 3rd harmonic above is -19 dB hence IMD is -19 dB

Giving an IMD Report

- Monitor the IMD measurement at the bottom of the screen
- Signal must be in IDLE (no typing, buffer empty)
- Check the S/N of the signal - it should be above 36 dB to get an accurate report

Things to look out for

- If S/N is too low, the IMD will be reported low
- If S/N is too high, the IMD may be reported low - because the receiver may clipping the signal - adjust the RF gain down if needed

Take an IMD measurement with a grain of salt

- If you are given a low IMD (say -19 dB) :
  - Have them use the spectrum display and check the S/N

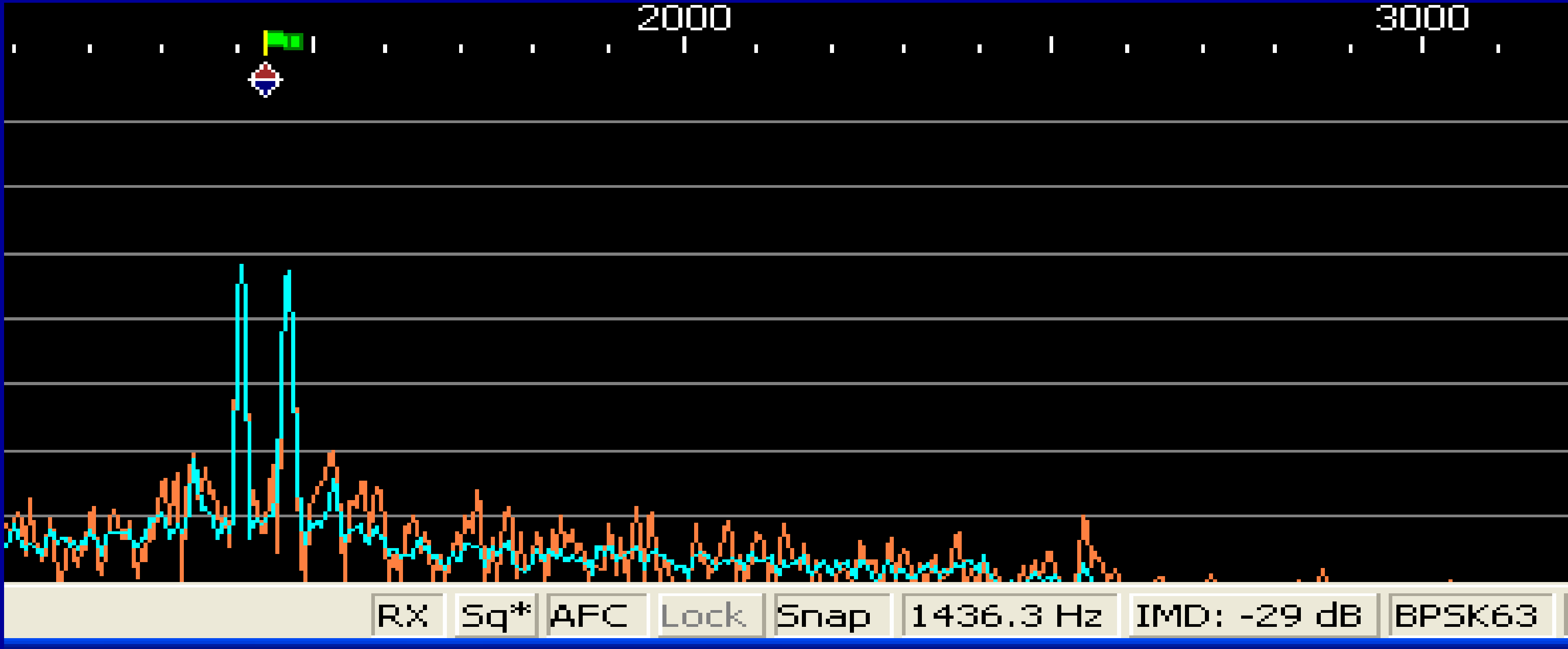
Let Your Eye Be Your Guide

- If the signal you are monitoring has S/N about -20 dB and IMD is about the same number:
  - If the signal looks clean i.e. straight sides, no apparent side bars, then the real IMD is probably -24 or better.

PSK31 Variations

- QPSK31 – Quadrature – 4 states instead of two (0 90 180 270 deg)
- BPSK63 – twice the data rate of BPSK31
  - Excellent for contests – comparable to RTTY in exchange turn around
  - Supported by MixW, Digipan and others
  - Sounds of BPSK63

BPSK63 Bandwidth



IDLE IMD -29 dB Bandwidth 130 Hz

Use 200 Hz spacing in practice